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GREEN PARK VILLAGE GROUND CONTAMINATION INTERPRETATIVE REPORT

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1. INTRODUCTION

1.1 Brief

Ramboll UK Limited (hereafter referred to as 'Ramboll') has been appointed by St Edward Homes Ltd to undertake a ground contamination interpretative report to support the proposed redevelopment of the site known as Green Park Village (GPV) (formerly Phase III of the Green Park Development), located on the southern fringe of Reading (hereafter referred to as the site).

This site is proposed for the development of commercial, community, educational and residential end uses. The site is divided into a number of phases, each of which will be redeveloped separately. Therefore, where necessary this report assesses conditions on a phase by phase basis.

This ground contamination interpretative report has been prepared to investigate potential land contamination issues and to assist design at the site.

The purpose of this report is to highlight potential ground contamination risks associated with the site and to identify where further assessment may be required to inform a strategy for addressing those risks. The information contained within this report was collated from previous geo-environmental desk based studies and intrusive ground investigations undertaken by Peter Brett Associates (PBA). Ramboll has not undertaken any intrusive investigation as part of this assessment.

This report does not constitute a geotechnical assessment of the site which is provided within a separate report reference: 1620000492/RPT/002 the GIR-DS.

1.2 Planning Context

It is understood that the site was granted Outline Planning Permission in 2011 under Application No 10/01461/OUT. This application was a hybrid application with full planning permission with no matters reserved for Phase 1 of the development and outline planning permission with all matters reserved for the subsequent phases of the development.

Planning permission included a number of conditions in relation to ground contamination. These are summarised below.

- Condition 42. Prior to the commencement of each phase of development approved by this planning permission (or such other date or stage in development as may be agreed in writing by the local planning authority), the following components of a scheme to deal with the risks associated with contamination in relation to that phase of development shall be submitted to and approved, in writing, by the local planning authority:
 1. A site investigation scheme, based on Phase I desk top study to provide information for detailed assessment of the risk to all receptors that may be affected, including those offsite.
 2. The investigation results and detailed risk assessment and, based on these, an options appraisal and remediation strategy giving full details of the remediation measures required and how they will be undertaken. The remediation measures shall include an implementation timetable and remediation verification methodology. The remedial scheme must be carried out before the development commences unless otherwise agreed in writing by the local planning authority.
- Condition 43. Should any unforeseen contamination be encountered during the development, of any phase of the scheme no further development (unless agreed in writing with the local Planning authority) of that phase of the scheme shall be carried out until the developer has submitted, and obtained written approval from the local planning authority for an amendment to the remediation strategy for that phase of the scheme detailing how this unsuspected contamination shall be dealt with. Any further investigation/remedial/protective works shall be carried out to agreed timescales and approved by the local planning authority in writing.

- Condition 44. Within one month of the completion of any required remediation being carried out for each phase of development, a Site Completion Report shall be submitted to an approved in writing by the local planning authority for that phase. The report must include:
 1. Confirmation that all remediation measures have been carried out fully in accordance with the approved remediation scheme. An appropriately qualified person shall oversee the implementation of all remediation.
 2. A long term monitoring and maintenance plan for longer term monitoring of pollutant linkages, maintenance and arrangements for contingency action and for the reporting of this to the local planning authority.
 3. If no contamination is encountered during the development, a letter confirming this fact shall be submitted to the local planning authority upon completion of the development.
- Condition 48. Piling or any other foundation designs using penetrative methods shall not be permitted other than with the express written consent of the local planning authority, which may be given for those parts of the site where it has been demonstrated that there is no resultant unacceptable risk to groundwater.
- Condition 49. No phase of development approved by this planning permission shall take place until a dewatering strategy for that phase has been submitted to and approved in writing by the local planning authority. The strategy shall be implemented in accordance with the approved details.

It is understood that St Edward Homes Ltd have applied for and received the discharge of Condition 42 in relation to Phase 1A of the development.

1.3 Proposed Development and Earthworks

The proposed site development plans are currently known in outline only (with the exception of Phase 1) and may be subject to change in the future. The plans of the proposed development are shown in Drawing PL-MPL-005.

The proposed development comprises approximately 737 residential properties, including housing with both private and communal gardens, a school, retirement care home, community uses, commercial premises and public open space. The proposed development also includes access roads and soft landscaping. The outline plans indicate the infilling of the north western portion of the Trout Lakes.

In order to facilitate the development a significant earthworks programme is proposed to be undertaken to bring the site to minimum level of +40.2mOD for flood alleviation purposes. The filling operation will involve the import of circa 600,000 m³ of material under a re-use of waste in construction bespoke environmental permit. Filling operations would be conducted under the material requirements of the Ramboll Specification for Earthworks¹. At the time of writing the permit application was still being considered.

Table 1 provides a description of the proposed development for each phase. See Drawings 4140564-1101 to 4140564-1104.

Table 1 Proposed Development at Each Phase

Phase	Proposed Development
Phase 1	For the purposes of the development programme, the Phase 1 area has been subdivided, with commencement within the Phase 1A part of the Phase 1 area having commenced. Phase 1 will comprise residential housing with gardens, areas of soft landscaping and associated infrastructure. The redevelopment will involve the demolition of all above ground structures and grubbing out of existing below ground features. As part of the redevelopment Phase 1 will be raised from an elevation of approximately 39 metres above Ordnance Datum

¹ Ramboll (July 2015). Specification for Earthworks ref 1620000492/SP/001 rev 04

Phase	Proposed Development
	(mAOD) in Phase 1 West (Phase 1B), and 39.5 mAOD to 40.2 mAOD in Phase 1 East (Phase 1A), to a consistent elevation of 40.25 mAOD. Stockpiles of soil which had been stored within the Eastern Triangle area (Phase 3 and 4), have been utilised for the purpose of land raising at Phase 1A. The land raising is required for flood alleviation purposes, and has already commenced within the Phase 1A area.
Phase 2 (including Phase 1C east)	Phase 2A will comprise a new care home facility with associated soft landscaping and car parking in the western part of Phase 2A. In addition there will be an area of residential apartments west of the care home building, the majority of which will be built over garages. Phase 2B will comprise a new primary school with sports pitches for dual school and local community use. Community facilities including a community hall are also to be provided. Residential development is proposed in Phase 2C, comprising a single block of residential units with communal areas of soft landscaping. The Phase 1C East area is proposed for construction of a new road with roundabout, and an area of green open space adjacent to the existing Trout Lakes. Ground levels are to be raised for flood protection purposes.
Phase 3, 4 and 5	Phase 3, 4 and 5 will comprise residential housing with gardens, areas of soft landscaping and associated infrastructure. Generally ground levels are proposed to be raised by approximately 2 m (in Phase 3 and 4) and 1.50 m in Phase 5. Ground levels are to be raised for flood protection purposes.
Phase 6 (including Phase 1c West and Phase 7)	Phase 6 will comprise commercial offices with areas of soft landscaping, associated infrastructure and a multi decked car park. Generally ground levels are proposed to be raised from between 38.5 mAOD and 39.9 mAOD (more commonly 39.5 mAOD) to 40.2 mAOD resulting in the placement of between 0.7 m and 1.7 m of fill upon existing ground levels. The outline plans also indicate the infilling of the north western portion of the Trout Lakes which will involve raising levels from approximately 35 mAOD to 40.2 mAOD (approximately 5.2 m of fill). The Phase 1C West and Phase 7 areas are proposed for construction of a new road and an area of green open space adjacent to the existing Trout Lakes. Ground levels are to be raised for flood protection purposes.

1.4 Objectives

The objective of this ground contamination interpretative report is to assess the potential liabilities and risks associated with potential contaminants in the ground and groundwater in accordance with current UK legislation and guidance.

1.5 Scope of Works

The scope of works for this ground contamination interpretative report is:

- i. To review previous reports pertinent to the site;
- ii. To identify the existing ground based site geo-environmental conditions based on desktop research and existing reports on the site;
- iii. To review potential sources of contamination on/or adjacent to the site from review of previous intrusive ground investigation works;
- iv. To illustrate the potential contamination risks to site specific receptors in a Preliminary Conceptual Site Model (CSM);
- v. To undertake a qualitative risk assessment based on a source-receptor-pathway in accordance with the provisions of Environment Agency (EA)/Department for Environment, Food and Rural Affairs (DEFRA) document CLR11 - Model Procedures for the Management of Land Contamination; and
- vi. To identify the requirement for further works, including intrusive ground investigation and remediation.

1.6 Previous Reports

A range of previous reports relating to the site have been made available to Ramboll, and this document draws on information from the following reports listed in Table 2.

Table 2 Existing Site Information Pertinent to Ground Conditions and Contamination

Report	Author	Date
Interim Report of Ground Investigation for Clembins Waste Transfer Station, Reading, Berkshire	Peter Brett Associates	June 2001
Geo-environmental Investigation for Phase III, Green Park, Reading	Peter Brett Associates	August 2002
Earthwork Material Suitability Assessment. Phase III, Green Park, Reading	Peter Brett Associates	November 2005
Green Park Village Environmental Statement Volume 1	Drivers Jonas	September 2007
Gas and Water Quality Monitoring Report, Green Park Village	Peter Brett Associates	July 2007
Phase 1 and 2 Ground Condition Assessment, Clembins Waste Transfer Station Site, Reading	Peter Brett Associates	September 2007
Report of Hydrogeological Risk Assessment, Green Park Village, Reading	Peter Brett Associates	January 2008
Phase 2 Supplementary Geo-environmental Ground Condition Assessment for the Pingemead Industrial Estate, Reading	Peter Brett Associates	April 2008
Report on Ground Condition Assessment – Phase 1 and 2. Green Park Station – Temporary Access Road and Park	Peter Brett Associates	February 2009
Report on Supplementary Phase 2 Ground Investigation and Tier 2 Risk Assessment. Green Park Railway Station, Reading	Peter Brett Associates	June 2009
Phase 2(d) – Report on Targeted Ground Investigation (Contamination Hotspots WS8 and BHC), Green Park Phase 3, Railway Station	Peter Brett Associates	October 2009
Synopsis Geo-environmental Report on Ground Conditions. Green Park Phase III – Green Park Village	Peter Brett Associates	July 2010
Report on Ground Investigation for Phase 1A. Green Park Village	Peter Brett Associates	May 2015
Specification for Earthworks	Ramboll	July 2015

1.7 Constraints and Limitations

The information presented within this report is based upon a review of the historical reports detailed in Table 2.

This report has been prepared for the exclusive use of St Edward Homes Ltd for the purpose of assisting its site evaluation in the context of the proposed development. This report may not be used in whole or in part by any third parties without the express permission of Ramboll in writing.

Ramboll has endeavoured to assess all information provided during this site appraisal. This report summarises information provided from a number of external sources and cannot offer any guarantees or warranties for the completeness or accuracy of information relied upon. Any substantial changes to the proposed development may require a reassessment of the implications of the risks identified.

Ramboll has reviewed the findings of these reports detailed in Table 2 but had no control over the input into these investigations. Any findings as part of this study are based upon our professional opinion of the data as presented by the third parties.

2. SITE SETTING

2.1 Site Location

The site is located approximately 4 km to the south of Reading town centre, Berkshire. The site occupies an area approximately 24.6 hectares (ha) at a National Grid reference (NGR) 469916,

170239, and is located immediately to the northwest of Longwater Avenue in Green Park. The southern boundary is formed by Smallmead Road and the western boundary of the site is the Reading-Basingstoke railway line. The site location plan is illustrated in Figure 1.

This report discusses Phases 1, 2 (Phase 1C East), 3, 4, 5 and 6 (including Phase 1C West and Phase 7) only. The boundaries of each phase considered in this report are shown in Figure 2.

2.2 Site Description and Environmental Setting

The site occupies an area of land which is immediately adjacent to authorised landfills (located north of the site) and historic landfills (located north and west of the site). Land at the site has been used for mineral extraction and landfilling at the western end of the site, with Pingemead Industrial Estate present in the central portion of the site.

In the western part of the site existing lakes, known as Trout Lakes are present which are surrounded by earth bunds. Green space is present in the eastern part of the site. It is also understood that a localised area of the eastern part of the site has been used for uncontrolled tipping in recent years.

Table 3 provides a description of each proposed development phase. The site features are shown on Figure 3.

Surrounding land uses within approximately 600 m of the site boundary include:

- i. Reading to Basingstoke railway line, located on the western boundary of the site;
- ii. A Recycling Centre, located approximately 330 m north of the site;
- iii. Green Park Business Park located adjacent to the site (to the southeast);
- iv. New Water Treatment Works, located approximately 100 m north of the site;
- v. Reading Stadium, located approximately 200 m north of the site;
- vi. The adjacent A33, flanked by commercial and light industrial developments;
- vii. Burghfield substation, located approximately 280 m northwest and Green Park substation, located approximately 68 m southwest of the site boundary; and
- viii. The M4 Motorway located approximately 540 m south of the site boundary.

Table 3 Site Phases

Phase	Approximate Area (ha)	Description
Phase 1	2.35 ha	The Phase 1 area is sited centrally within the GPV site, and is bounded by the existing Trout Lakes to the west, a ditch at the southernmost boundary. For the purposes of this assessment, the Phase 1 area has been considered to comprise multiple parcels of land, which are discussed separately where relevant. Phase 1A West and Phase 1B: The area to the west of the north-south trending ditch is currently used as a vacant industrial estate known as Pingemead Industrial Estate, and includes various northwest elongated, brick built, single storey industrial buildings. The industrial units within Phase 1A West and Phase 1B were originally farm buildings, but have since been utilised for a variety of light industrial purposes. These uses include vehicle repairs, bodywork and servicing, metal fabricators, oil distribution and photo copier repairs. As part of these land uses, the industrial estate has: Various disused above ground oil storage tanks (both existing and historic), cess pits, disused spray booths and an extractor unit with associated paint and thinner storage. Phase 1A East: The Phase 1 area to the east of the ditch is currently disused. An area of trees lines the eastern side of the ditch, beyond which is open land. Along the southern boundary of the Phase 1A East area is a further tree-lined ditch. Soil stockpiles were placed within the Phase 1 area during the end of 2015 and start of 2016 to raise ground levels.
Phase 2 (including Phase 1C East)	2.10 ha	The Phase 2 and Phase 1C East area is sited centrally at the south-central part of the GPV site, and is bounded by the existing Trout Lakes to the west, a ditch at the south-easternmost boundary, Smallmead Road to the south boundary, and Phase 1 area to the north and east.

Phase	Approximate Area (ha)	Description
		Land at Phase 2 is predominantly disused and includes existing disused houses in Phase 2A, one of which was previously used as the GPV site office. Phases 2A and 2C incorporate the access road serving the derelict Pingemead Industrial Estate. Phase 2C incorporates the south eastern corner of Pingemead Industrial Estate which lies on the east side of a north-south trending ditch, and vacant land to the west side of that ditch. The industrial units within Phase 2B West were originally farm buildings, but have since been utilised for a variety of light industrial purposes. These uses include vehicle repairs, bodywork and servicing, and metal fabricators. As part of these land uses, the industrial estate has various disused above ground oil storage tanks (both existing and historic) and cess pits. The Phase 2B East area to the east of the ditch is currently disused. An area of trees lines the eastern side of the ditch, beyond which is open land. Along the south-eastern boundary of the Phase 2B East area is a further tree-lined ditch.
Phase 3	4.50 ha	Phase 3 is sited in the eastern portion of the site, and is bounded by historic landfill sites to north, a ditch at the southernmost boundary, and other Phase areas (Phases 1 and 4) to the west and north. Early Ordnance Survey mapping (1883) indicates that Phase 3 was undeveloped open land known as "Smallmead Common". By 2008 a training centre belonging to Thames Valley University and subsequently used as a maintenance and security depot were noted within the centre of Phase 3. Whilst Phase 3 is undeveloped open ground there was evidence of re-profiling of the ground and soil stockpiling. These stockpiles have been utilised for the purpose of land raising in Phase 1A. It should be noted that Phase 3 was referred to as the 'Eastern Triangle' within the previous ground investigation reports undertaken by PBA.
Phase 4	2.50 ha	Phase 4 is sited on the north eastern portion of the GPV site, and is bounded by historic landfill sites and a ditch to the north. Early Ordnance Survey mapping (1883) indicates that Phase 4 was undeveloped open land known as "Smallmead Common". Whilst Phase 4 is undeveloped open ground there was evidence of re-profiling of the ground and stockpiling. These stockpiles have been utilised for the purpose of land raising in Phase 1A. It should be noted that Phase 4 was referred to as the 'Eastern Triangle' within the previous ground investigation reports undertaken by PBA.
Phase 5	2.10 ha	Phase 5 is sited on the northern (central) portion of the GPV site and is split by an approximate north-south trending tree-lined ditch. Early Ordnance Survey mapping (1883) indicates that Phase 5 was undeveloped open land known as "Smallmead Common". By the 1990s the area to the west of the north-south trending ditch was a vehicle storage area belonging to Pingemead Industrial Estate. The area to the east of the (north-south) ditch is undeveloped open land with evidence of re-profiling of the ground and stockpiling. These stockpiles have been utilised for the purpose of land raising in Phase 1A. It should be noted that the eastern portion of Phase 5 was referred to as the 'Eastern Triangle' within the previous ground investigation reports undertaken by PBA.
Phase 6 (including Phase 1c West and Phase 7)	3.10 ha	Phase 6 contained an historic waste transfer and treatment facility referred to as "Clembins". It was noted by PBA (July 2010) that mounds of stockpiled material, skips and site buildings were present until 2007, when operations at this facility ceased. Prior to Clembins this portion of land was part of an active landfill referred to as Burghfield landfill and also a historic landfill referred to as Burghfield Area D under licence reference 86253. Currently the site is disused and derelict formed of mostly level scrub land. Phase 6 also contains the north-western smaller Trout Lake which is to be filled as part of the development proposals. Phase 1c West is sited centrally at the south-central part of the GPV site, and is bounded by the existing Trout Lakes to the north, Smallmead Road to the south boundary, Phase 6 to the west and Phase 1C to the east.

Phase	Approximate Area (ha)	Description
		Phase 7 is sited centrally at the north-central part of the GPV site, and is bounded by the existing Trout Lakes to the south, historic landfills to the north, Phase 6 to the west and Phase 5 to the east.

2.3 Topography

The topography of the site is generally flat and has been altered by historic gravel extraction and bulk fill excavations. Within all phases at the site ground levels are at a level, varying from 38 mAOD to 40 mAOD, although local variations are present at the margins of the site and in the onsite ditches.

The southern and western area of the site bordering Smallmead Road and the railway line is at an approximate elevation of 40 mAOD and falls gently to the east, where the ground level is at an approximate elevation of 38 mAOD.

2.4 Site History

The site history has been assessed from a review of the previous reports obtained from PBA; and is summarised within Table 4.

Table 4 Site History

Date	Descriptions
1880s	- The site was designated as Smallmead Common. - The site was agricultural land with the western portion subdivided into smaller fields. - Smallmead Farm and cottages were located on the southern perimeter of the site. - The Reading to Basingstoke railway line was located adjacent to the western perimeter of the site. - Some workings were present (possibly borrow pits) near the western perimeter of the site, adjacent the railway line. - Smallmead Road and Kybes Lane were present along the southern perimeter of the site.
1900s	- The site was still agricultural land. - Smallmead Farm was no longer present on the 1900s historic map. - Smallmead cottages were still present on the southern perimeter of the site. - A new farm (Farm 2) was located 30 m offsite to the south. - A gravel pit was noted in the north eastern portion of the site (Phase 4). - The workings (possible borrow pits) in the western portion of the site were no longer present. - Manor Farm Sewerage Works were located 100 m to the northeast of the site.
1960s	- The site was still agricultural land. - The gravel pit noted on the 1900s historic map was still present onsite. - Some workings (possibly gravel pits) were located by Searls Farm (300 m to the west of the site). - A small structure was located on the southern perimeter of the site.
1970s	- The western portion of the site was occupied by gravel workings (the Trout Lakes). - The remainder of the site was open land. - A building was located within the centre of the site (Pingemead Industrial Estate). - To the north of the site, to the southwest at Kirtons Farm and to the northeast at the sewage works and Island Road, active gravel pits were indicated. - At Searls Farm the workings identified on the earlier maps were significantly extended. - To the northeast of the site the extent of the sewerage works and associated former sludge beds were delineated. - Smallmead Farm was extended with several additional buildings. - Approximately 100 m to the southeast of the site was a 'refuse tip' (at present known as Smallmead 'tip'). - Burghfield electricity substation was noted 280 m northwest of the site. - A speedway stadium was erected to the northeast of the site on the disused sludge beds.
1980s	- Several buildings associated with Pingemead Industrial Estate were located within the central portion of the site. - The gravel workings to the north of site (operated by Halls Aggregates) were extended.

Date	Descriptions
	- Additional gravel workings occurred at the Kirtons Farm to the southwest of the site. - The former workings at the sewage works and Island Road were in filled. - The M4 motorway was constructed 540 m to the south of the site.
1990s	- In 1992, four lakes forming the Trout Lakes were combined following an earlier Green Park construction phase and the north western lake was partially backfilled (the type of materials used is unknown). - It was understood by PBA that the Trout Lakes were deepened in the mid-1990s to gain fill material for construction. - The 1992 map indicate an brewery 1 km southeast of the site boundary
2000s	- A waste transfer and treatment facility was located on the western portion of the site (Phase 6). It was noted that mounds of stockpiled materials, skips and site buildings were present until 2007, when operations at the facility ceased. - Within the eastern portion of the site (Phase 3) a training centre belonging to Thames Valley University was first shown on the historical maps dated 2008. - A flood relief channel was constructed, approximately 200 m northeast of the site.

2.5 Unexploded Ordnance

The online Zetica UXB map for Berkshire identifies the site as being at low risk from unexploded ordnance. Areas designated as low risk are those that show a density of bombing hits of less than 10 bombs per 1000 acresⁱⁱ.

3. GROUND CONDITIONS AND ENVIRONMENTAL SETTING

3.1 Summary of Previous Ground Investigations

The site has been subject to a series of predominantly geo-environmental desk based studies and intrusive ground investigations. The ground investigation works were undertaken by PBA from 2001 to 2015. Table 5 provides a summary of the ground investigation reports that have been made available for review and includes a summary of the scope of works. Figure 4 illustrates all the historic ground investigations undertaken at the site. Figures 5 to 11 show all the historic ground investigations undertaken per phase.

Table 5 Summary of Previous Ground Investigations

Report	Date	Ground Investigation	Depths (m bgl)
Interim Report of Ground Investigation for Clembins Waste Transfer Station, Reading, Berkshire	June 2001	Two shell and auger boreholes (BH6 to BH7)	Up to 10
		Five window sample boreholes (BH1 to BH5)	0.5 to 5.0
		Nine trial pits (TP1 to TP9)	1.8 to 3.4
Geo-environmental Investigation for Phase III, Green Park, Reading	August 2002	Eleven boreholes (BH101 to BH111)	5.0 to 30.0
		Eight Boreholes (BHG1 to BHG8)	Up to 5.0
		Seven window sample boreholes (WS1 to WS7)	3.0 to 4.0
		Eighteen trial pits (TP201 to TP218)	Up to 4.0
		One borehole BH1_1987 * ¹	Up to 16.8
		One borehole 14C_1984 * ²	Up to 21.86
Earthwork Material Suitability Assessment. Phase III, Green Park, Reading	November 2005	Four window sample boreholes (G15 to G18)	2.0 to 3.0
		Thirteen trial pits (TP219 to TP231)	2.5 to 4.5

ⁱⁱ Zetica – Unexploded Ordnance (UXO) Risk Map for Berkshire (2016)

Report	Date	Ground Investigation	Depths (m bgl)
Gas and Water Quality Monitoring Report, Green Park Village	July 2007	Six window sample boreholes (G9 to G14) * ³	Up to 4.5
		One borehole (BH112) * ⁴	Up to 10
Phase 1 and 2 Ground Condition Assessment, Clembins Waste Transfer Station Site, Reading	September 2007	Six cable percussion boreholes (BHA to BHF)	4.5 to 5.5
		Eight window sample boreholes (WS1_2007 to WS8_2007)	2.8 to 5.0
		Twelve trial pits (TPA to TPL)	1.6 to 3.9
Phase 2 Supplementary Geo-environmental Ground Condition Assessment for the Pingemead Industrial Estate, Reading	April 2008	Seven hollow stem auger boreholes (WS08/01, WS08/03, WS08/04, WS08/05, WS08/06, WS08/08, WS08/09)	3.8 to 4.6
Report on Ground Condition Assessment – Phase 1 and 2. Green Park Station – Temporary Access Road and Park	February 2009	Twelve trial pits (TPA01 to TPA12)	0.5 to 2.5
Report on Supplementary Phase 2 Ground Investigation and Tier 2 Risk Assessment. Green Park Railway Station, Reading	June 2009	Seven boreholes BH2009/01 to BH2009/07	5 to 20
		Fourteen trial pits (TP301 to TP314)	Up 2.9
		RGPTP01 to RGPTP04 * ⁵	Up to 0.5 to 2.5
		RGPST02 to RGPST03 * ⁶	Up to 2
		RGPWS01 to RGPWS05 * ⁷	Up to 5
		BH_2007_2009 * ⁸	14.35
Phase 2(d) – Report on Targeted Ground Investigation (Contamination Hotspots WS8 and BHC), Green Park Phase 3, Railway Station	October 2009	Eleven trial pits (TP6001 to TP6011)	Up 4.5
Synopsis Geo-environmental Report on Ground Conditions. Green Park Phase III – Green Park Village	July 2010	TP1047 to TP1048 * ⁹	Up to 5
		BH1016 * ¹⁰	Up to 12
Report on Ground Investigation for Phase 1A. Green Park Village	May 2015	Four window sample boreholes (WS01_2015 to WS04_2015)	2.5 to 4
		Nineteen trial pits (TP101 to TP119)	0.8 to 3.8

Referenced only within the named report (not part of the intrusive ground investigation)

*1, *9 and *10: Geo-technics

*2: Geoffrey Walton

*3 and *4: CJ Associates

*5, *6, *7 and *8: Scott Wilson

3.2 Geology

The site geology has been assessed from a review of 1:50,000 scale digital geological mapping information obtained from the British Geological Survey (BGS) website and from previous intrusive ground investigations undertaken by PBA.

Information from the various historic investigations at the site indicates that the typical ground conditions comprise Topsoil and Made Ground, underlain by Alluvium; River Terrace Deposits of the

Thames Group (drift), overlying the Lambeth Group, which in turn is underlain by the White Chalk Subgroup. The geological profile of the site is summarised in Table 6. See Drawings 1620000492-RAM-GDR-00-DR-CG-001 to 1620000492-RAM-GDR-00-DR-CG-005.

Table 6 Geological Profile Site Wide

Stratum	Typical Description	Aquifer Classification*	Depth Range of Strata (m bgl)	Maximum Thickness (m)
Topsoil (TS)	Dark brown silty clay with occasional fine gravel	Unclassified	Ground level to 0.3	Up to approximately 0.4 m
Made Ground (MG)	Mainly at the former landfill area (western portion of the site), with localised pockets of Made Ground elsewhere. Bund material from the Trout Lakes typically is clayey with fragments of anthropogenic material. The area to the west of Phase 6 is thought to comprise an area of former workings which have been in-filled and the Alluvium and River Terrace Deposits appear to have been removed from these areas.	Unclassified	Ground level to 5.0	Up to approximately 4.7 m thick, occasionally thicker in some places
Alluvium (ALL)	Soft to firm silts and clays with sandy lenses	Unproductive strata	0.05 to 4.50	Approximately 0.1 m to 2.9 m thick. Locally absent
River Terrace Deposits (RTD)	Sand and gravel	Secondary A	0.30 to 6.00	Approximately 0.1 m to 3.5 m thick
Reading Formation of the Lambeth Group (LMB)	Mottled (red/brown, grey) silty sandy clay with some sandy beds	Secondary A	1.9 to 20.2	Approximately 12.9 m to 15.55 m
White Chalk Subgroup (CHK)	Chalk with flints. Commonly recovered as putty chalk	Principal	15.7 to 30 (depth not proven)	Thickness not proven

* Principal Aquifers - these are layers of rock or drift deposits that have high intergranular and/or fracture permeability - meaning they usually provide a high level of water storage. They may support water supply and/or river base flow on a strategic scale. In most cases, principal aquifers are aquifers previously designated as major aquifer.

* Secondary A - permeable layers capable of supporting water supplies at a local rather than strategic scale, and in some cases forming an important source of base flow to rivers. These are generally aquifers formerly classified as minor aquifers.

* Unproductive Strata- These are rock layers or drift deposits with low permeability that have negligible significance for water supply or river base flow

3.3 Hydrogeology

Groundwater bodies have been identified in the superficial strata and in the bedrock beneath the site. The River Terrace Deposits and Lambeth Group are classified as Secondary A Aquifers by the Environment Agency (EA) and the White Chalk Subgroup is classified as a Principal Aquifer. The elevation of the piezometric head within these groundwater bodies differs, and it is likely that they form separate water bodies, although there may be some hydraulic continuity in places.

In the superficial strata, groundwater has been identified with approximate piezometric head elevations of 37 mAOD to 38 mAOD with a groundwater flow direction towards the northeast. In the Lambeth Group, groundwater piezometric head elevation has been recorded at approximately 36 mAOD to 38 mAOD with a flow direction towards the east or southeast. Groundwater in the White Chalk Subgroup has been less well characterised, but most likely flows towards the east/southeast with groundwater piezometric head elevations between approximately 35 mAOD and 38 mAOD. The GPV site is not within a Nitrate Vulnerable Zone (NVZ).

There is a disused (but actively licensed) abstraction (licence number: 28/39/22/0463) at NGR 469900, 170180 in the name of Kennet Valley Park Limited located within the centre of Pingemead Industrial estate (Phase 1). This was a private water supply used for drinking, cooking, sanitary and washing. The presence of the licence means that parts of the site (Phase 1 and Phase 2) are within a groundwater Source Protection Zone (SPZ). Any current associated source protection zone will become irrelevant once the abstraction well is decommissioned and the site is developed.

In addition a historic abstraction was located at Smallmead Farm at an approximate grid reference of 469900,170100. This abstraction abstracted waters from the Chalk at 45.72 mbgl but is understood to be disused and decommissioned.

Further groundwater abstractions have been identified at Smallmead Landfill located to the northwest of the site where groundwater is abstracted to facilitate the landfill works, according to PBA's June 2009 report.

Regional groundwater quality was described in PBA's June 2009 report, based upon Environment Agency (EA) data from seven monitoring wells. W14, W14A and W14C located approximately 750 m north of the site, W20 and W20A present in the north-western part of the site and W21 and W21A present approximately 300 m north of the site and adjacent to Smallmead Landfill. This data shows background concentrations of iron and manganese to be high in the River Terrace Deposits, Lambeth Group and the White Subgroup Chalk.

In 2009 PBAⁱⁱⁱ undertook tests to ascertain hydraulic conductivity (K) values in the Lambeth Group, and identified that the Lambeth Group provides protection to the White Chalk Subgroup from the poor quality shallow groundwater. Falling head tests and triaxial permeability tests in the Lambeth Group gave results for low K values of between 9.4×10^{-8} m/s and 5.2×10^{-11} m/s. These values indicate soils to have low permeability, which is expected given the description of the strata on the geological logs as fine sands, silts and clays. There is no current data pertaining to the hydrogeological properties of other geological strata at the site.

3.4 Hydrology

Foundry Brook is present to the east of the site, being approximately 350 m from the site boundary and flowing to the northeast. The other water features include Trout Lakes (located in the western portion of the site) which represent flooded, former gravel workings. Several drainage ditches are present on site, including a drainage ditch at the eastern boundary of Pingemead Industrial Estate which is understood to flow in a southerly direction. A drainage ditch is also present at the northern boundary of the site which flows in an easterly direction where it joins Foundry Brook.

The River Kennet is present approximately 650 m to the north of the site, running in a west-east direction and flowing to the east. A flood relief channel (200 m northeast of the site) was constructed as part of the Green Park Development flowing in a northerly direction and is understood to be clay lined.

3.5 Ground Gas and Radon

There are a number of potential sources of ground gas on site. In summary these comprise:

- i. Landfill(s) on site;
- ii. Landfills near to the site;
- iii. Backfilled gravel and borrow pits;
- iv. Made Ground on site; and
- v. Natural strata (Alluvium and the Chalk).

Ground gases have the potential to be mobilised as a result of the proposed development, for example, via pathways created along piles or due to compression resulting from increased loads.

ⁱⁱⁱ Peter Brett Associates (June 2010) Synopsis Geo-environmental Report on Ground Conditions. Green Park Phase III – Green Park Village

The Health Protection Agency Radon Atlas shows that the site is in an area where 0% to 1% of homes are above the UK Action Level for radon. Guidance provided in BRE211 Radon: Guidance on Protection Measures for New Dwellings indicates that radon protection measures are not required in this area.

4. ASSESSMENT METHODOLOGY

4.1 Approach

The reports provided by other consultants relating to the site have been produced over a long time period, during which there have been changes in the way that land affected by contamination is assessed.

The ground contamination assessment within this report has been undertaken in accordance with the current UK framework and comprises a generic quantitative risk assessment (GQRA) as defined in Contaminated Land Report CLR 11^{iv}.

The risk assessment has been undertaken following the procedures set out within the guidance document for the Safe Development of Housing on Land Affected by Contamination (National House Building Council (NHBC) and the Environment Agency (EA), 2008)^v. Further details of the UK legislative context and methodologies are provided in Appendix 1.

In order to assess the significance of the chemical concentrations reported, generic assessment criteria (GAC) have been selected based on the critical receptors identified at the site. Receptors are considered in relation to human health (e.g. people using the site) and the water environment (e.g. water resources). Where relevant, impacts upon below ground structures and infrastructure are also considered. An assessment of aggressive ground conditions is not within the scope of this report.

A five 5 metre buffer zone was chosen to capture relevant data of soil conditions adjacent to the site which might also be representative of conditions on site.

4.2 Human Health Assessment - Soil Screening Analysis

4.2.1 Methodology

Details of the UK framework for human health risk assessment and GAC are provided in Appendix 1. Contaminant concentrations below the adopted GAC are considered not to warrant further risk assessment. Where any concentrations are recorded above the GAC consideration of the contaminant distribution is undertaken.

Current UK guidance is provided in the Defra/EA CLR framework which sets out standard land uses for which GAC are derived for individual contaminants. As parts of the site (Phase 1 to Phase 5) are to be used for residential development and it is proposed to locally transfer soils at the site to other locations, comparison has been made to GAC for a residential with plant uptake end use, as a preliminary worst case scenario.

Phase 6 will comprise commercial premises with areas of soft landscaping, associated infrastructure and a multi-decked car park. Therefore Phase 6 comparison has been made to GAC for a commercial/industrial end use, as a preliminary worst case scenario.

4.3 Controlled Waters Assessment – Soil Leachate and Groundwater

4.3.1 Methodology

Adopting a conservative approach (and on the basis that the licensed potable abstraction in the Pingemead Industrial Estate will be decommissioned as part of the redevelopment), comparison of

^{iv} Environment Agency (2004) Model Procedures for the Management of Land Contamination. CLR11

^v NHBC and Environment Agency 2008. Guidance for the Safe Development of Housing on Land Affected by Contamination. R&D Publication 66: 2008

concentrations of determinants in leachate and groundwater has been made to Environmental Quality Standards (EQS) for freshwater and, where these are not available, to UK Drinking Water Standards (DWS). The GAC used in the assessment of controlled waters are also provided in Appendix 1.

4.4 Ground Gas Risk Assessment

4.4.1 Methodology

The gas regime at the site has been characterised using the guidelines provided in CIRIA Report C665 2007^{vii}, BS8485 2015^{viii} and RSK/NHBC 2006^{ix}. Further details of the assessment methodology are provided in Appendix 1.

5. ASSESSMENT OF PHASE 1

5.1 Site Setting

The Phase 1 area is located centrally within the GPV site, and is bounded by the existing Trout Lakes to the west, a ditch at the southernmost boundary, and other Phase areas (Phases 2, 3 and 4) to the north, south and east. See Figure 2.

For the purposes of this assessment, the Phase 1 area has been considered to comprise multiple parcels of land, which are discussed separately where relevant. It is divided into Phase 1A and Phase 1B according to the development programme whereby Phase 1A is proposed to be constructed first. Phase 1A is further split by an approximate north-south trending tree-lined ditch which cuts through the Phase 1A area, as is shown on Figures 2 and 5, into Phase 1A West (west of the ditch) and Phase 1A East (east of the ditch).

Phase 1A West and Phase 1B: The area to the west of the north-south trending ditch is currently used as a vacant industrial estate known as Pingemead Industrial Estate, and includes various north-west elongated, brick built, single storey industrial buildings. Each of the buildings is sub-divided approximately in half such that separate industries could access the buildings from the north and south. The industrial estate closed in December 2015.

The industrial units within Phase 1A West and Phase 1B were originally farm buildings, but have since been utilised for a variety of light industrial purposes. These uses include vehicle repairs, bodywork and servicing, metal fabricators, oil distribution and photo copier repairs. As part of these land uses, the industrial estate has: Various disused above ground oil storage tanks (both existing and historic), cess pits, disused spray booths and an extractor unit with associated paint and thinner storage. A plan showing the potential contaminative uses of the industrial estate is provided in Figure 3. From a site walkover conducted by Ramboll consultants in January 2016, the recently derelict industrial estate was noted to be in poor condition, with various waste debris and discarded chemical containers distributed across the industrial estate area. The condition of the industrial estate suggests that general housekeeping by the industries which utilised it may have been poor.

The western boundary of the Phase 1B area comprises a vegetated earth bund, beyond which is Trout Lake. From site inspections undertaken by Ramboll consultants, it has been noted that this earth bund contains various types of waste debris.

The north-south trending ditch which separates the Phase 1 area has been noted by Ramboll consultants during a site visit in January 2016 to be blocked by various waste and debris.

Phase 1A East: The Phase 1 area to the east of the ditch is currently disused. An area of trees line the eastern side of the ditch, beyond which is open land. Along the southern boundary of the Phase 1A East area is a further tree-lined ditch. Soil stockpiles were present within the Phase 1A East area in

^{vii} CIRIA (2007) Assessing Risks Posed by Hazardous Ground Gases to Buildings. C665

^{viii} British Standards Institution (2015) Code of Practice for The Design of Protective Measures for Methane and Carbon Dioxide Ground Gases for New Buildings. BS8485-2015

^{ix} National House Building Council (NHBC) (2006) Guidance on Evaluation on Development Proposals on Sites Where Methane and Carbon Dioxide Are Present, Incorporating 'Traffic Lights'

2015, but were re-distributed across Phase 1 East area during the latter part of 2015 in order to raise ground levels. As such, the locations of soil sampling from stockpiles may not be representative of the current locations of that soil. During placement, material within the stockpiles was subject to sorting in accordance with the Specification for Earthworks. This sorting included the removal of potentially degradable material such as wood and chalk. Plaster board, metals and plastics were also stipulated within the Specification for Earthworks as being unsuitable for use within placed fill materials.

Within the area of Pingemead Industrial Estate, an existing water supply well is present, but is disused. It is understood that a licence to abstract groundwater for private supply is in existence for this well and relates to the previous land owners. The proposed development scheme does not include for any groundwater abstraction, and therefore there is no requirement for the protection of groundwater with respect to the disused water supply well at Phase 1. Any current associated source protection zone will therefore become irrelevant once the site is developed.

5.2 Phase 1A Development and Proposals for the Phase 1 Area as a Whole

With respect to Phase 1A, the Local Authority has accepted site investigation and assessment data submitted to them, comprising a series of reports produced by PBA, to demonstrate that further investigation, assessment and remediation are not required. This has allowed development to commence within Phase 1A, and the area of Phase 1A East has been subject to land raising and housing construction. Based upon the PBA assessments, no further investigation and assessment nor any remediation, ought to be required in Phase 1A East.

Phase 1 will comprise predominantly residential housing with private and communal gardens, parking areas, areas of soft landscaping and associated infrastructure. In addition, in the southern part of Phase 1, an area of public space, known as the 'Market Square' is proposed, which will comprise mixed soft and hard landscaping.

The redevelopment will involve the demolition of all above ground structures and grubbing out of existing below ground features. As part of the redevelopment the site will be raised from an elevation of approximately 39 mAOD in Phase 1A West and Phase 1B, and 39.5 mAOD to 40.2 mAOD in Phase 1A East, to a consistent elevation of 40.25 mAOD.

Stockpiles of soil which had been stored within the Eastern Triangle area, have been utilised for the purpose of land raising at Phase 1A East.

The land raising is required for flood alleviation purposes, and has already commenced within the Phase 1A East area.

5.3 Summary of Exploratory Locations in Phase 1

Table 7 below provides a summary of exploratory holes advanced within Phase 1, including details of monitoring well installations, groundwater strikes and visual/olfactory evidence of contamination.

Table 7 Summary of Exploratory Locations in Phase 1

ID	Depth to Base of Hole (m bgl)	Groundwater Strike (m bgl)	Response Zone (m bgl)	Response Zone Strata	Visual/olfactory Evidence of Contamination
BH105	25	0.65	20.00 - 25.00	Chalk	None
WS5	4	1	1.00 - 4.00	River Terrace Deposits and Lambeth Group	Occasional brick fragments and paper fragments
WS6	4	1.55	-	-	None
TP202	1.85	1.5	-	-	None
TP224	4.5	Dry	-	-	Occasional fragments of clay pipe and organic material (roots)

ID	Depth to Base of Hole (m bgl)	Groundwater Strike (m bgl)	Response Zone (m bgl)	Response Zone Strata	Visual/olfactory Evidence of Contamination
WS08/03	4.1	No record	1.10 - 4.10	Alluvium and River Terrace Deposits and Lambeth Group	Rare fragments of brick
WS08/04	3.8	No record	1.00 - 3.80	Alluvium and River Terrace Deposits and Lambeth Group	Occasional fragments of <200 mm of red bricks
WS08/05	4.2	No record	1.00 - 4.10	Alluvium and River Terrace Deposits and Lambeth Group	None
WS08/06	No record	No record	1.00 - 3.80	No record	No record
WS08/08	No record	No record	1.00 - 3.80	No record	No record
WS08/09	No record	No record	1.00 - 4.30	No record	No record
TP101	1.8	Dry	-	-	Stockpile; occasional shell fragments, plastic and organic material (roots)
TP103	2.4	No record	-	-	None
TP104	2.9	No record	-	-	Stockpile; occasional brick and concrete cobbles, metal fragments and organic material (roots)
TP105	3	2.9	-	-	Stockpile; occasional metal fragments, timber, compressed organic material
TP106	2.7	2.6	-	-	Occasional concrete cobbles (kerbstones), timber fragments and organic materials (roots)
TP108	2.7	Dry	-	-	Stockpile; occasional flint gravel, plastic, tarmac, concrete cobbles, metal fragment, brick fragments and organic materials (roots)
TP112	2.7	Dry	-	-	Stockpile; occasional brick and drain fragments
TP113	3.5	1.3	-	-	Stockpile; occasional brick fragments, concrete, burnt timber, burnt flints, ceramics
Contained within the 5 m buffer zone					
WS08/01	4.5	No record	1.00 - 4.50	Alluvium and River Terrace Deposits and Lambeth Group	Fragments of brick, tarmac and clinker
TPA02	0.5	No record	-	-	Asbestos cement sheeting, brick and clinker
TPA03	1.5	0.5	-	-	None

5.4 Evaluation and Assessment of Results

The evaluation and assessment of results is based upon review of the following reports:

- i. PBA (2002) Geo-environmental Investigation for Phase III, Green Park, Reading BH105, WS5, WS6, TP202;
- ii. PBA (2005) Earthwork Material Suitability Assessment. Phase III, Green Park, Reading TP224;
- iii. PBA (2009) Report on Ground Condition Assessment – Phase 1 and 2. Green Park Station – Temporary Access Road and Park TPA02, TPA03, WS08/01, WS08/03-06, WS08/08-09; and
- iv. PBA (2015) Report on Ground Investigation for Phase 1A. Green Park Village TP101, TP103, TP104-106, TP108, TP112, TP113.

5.4.1 Soil Results – Human Health Risk Assessment

As the Phase 1 area of the site is proposed for redevelopment for a residential end use, the concentrations of substances in soil have been assessed by comparison to GAC for a residential with plant uptake end use (see Appendix 2).

Testing for a range of metals and metalloids, total petroleum hydrocarbons (TPH), polycyclic aromatic hydrocarbons (PAHs) and phenols was routinely undertaken within Phase 1 area from both Made Ground and the natural strata. The majority of samples were obtained from the Made Ground. In selected areas of the site, testing was also undertaken for other semi-volatile organic compounds (SVOCs) and volatile organic compounds (VOCs).

Metals and Metalloids

Lead

At WS5, TP202, TP224, WS08/01, WS08/03, WS08/05, WS08/06, WS08/08, TP105-106, and TP112, lead was tested for in shallow soils but was identified at concentrations less than or equal to the residential GAC of 200 mg/kg (see Figure 15).

Concentrations of lead which are elevated above residential GAC were identified at two locations only. Both occur in the upper 0.5 m of Made Ground at Pingemead Industrial Estate in the Phase 1A West and Phase 1B areas, namely:

- i. WS08/04 (360 mg/kg); and
- ii. WS08/09 (210 mg/kg).

These positions are located between the existing industrial buildings.

Chromium

Previous ground investigations undertaken at the Phase 1 area have tested for 'total chromium'. It is not possible to ascertain from the results provided to which chromium oxidation state the recorded concentrations relate. As a 'worst case', the chromium would comprise entirely chromium in its most toxic form, hexavalent chromium. In reality, this is unlikely to occur owing to there being no specific source for hexavalent chromium nor expected redox conditions which might make hexavalent chromium stable at the site.

The GAC for hexavalent chromium in a residential setting is 21 mg/kg. Trivalent chromium is the more common and stable form of chromium, for which the GAC is 910 mg/kg.

Concentrations of chromium which are elevated above residential GAC were identified at four locations only. They all occur in the upper 0.5 m of Made Ground at Pingemead Industrial Estate in the Phase 1A West area and Phase 1B area, namely:

- i. WS08/01 (23 mg/kg)
- ii. WS08/03 (37 mg/kg);
- iii. WS08/04 (31 mg/kg);
- iv. WS08/06 (33 mg/kg); and

v. WS08/08 (28 mg/kg).

These positions are located in the area of the existing industrial buildings. Given that the maximum recorded concentration of total chromium is only marginally higher than the GAC for hexavalent chromium, no significant risks from chromium are considered likely to be realised (see Figure 13).

Mercury

Previous ground investigations undertaken in the Phase 1 area have tested for 'mercury'. The results of testing do not indicate whether the mercury is elemental, inorganic or methyl. As there is no specific source in the Phase 1 area for mercury contamination in its elemental form, it is unlikely that elemental mercury occurs at this part of the site.

The residential GAC for mercury varies between 0.17 mg/kg and 1.2 mg/kg in its elemental form (soil organic matter dependent), between 7.4 mg/kg and 11 mg/kg in its methyl form (soil organic matter dependent), and is 40 mg/kg for inorganic mercury.

Mercury was identified in shallow Made Ground in the Phase 1A East area at concentrations above the residential GAC at two locations:

- i. TP106 (2.4 mg/kg); and
- ii. TP103 (1.5 mg/kg).

There is a low likelihood that these mercury concentrations relate entirely to elemental mercury, and therefore it is unlikely that the recorded mercury concentrations represent a risk to end users at the site (see Figure 14).

Other Metals and Metalloids

Concentrations of all other metals and metalloids (e.g. arsenic, cadmium, copper, nickel, selenium and zinc) were all recorded at concentrations below the residential GAC.

Summary

Elevated concentrations of lead and chromium have been identified in the shallow (up to 0.5 mbgl) Made Ground at Pingemead Industrial Estate. Due to the proposal to raise site levels across this area of the site by over a metre, any pollutant linkage to end users would be mitigated by the development design. The Made Ground from the industrial estate area would not however be likely to be suitable for reuse elsewhere within the site unless deemed appropriate through specific testing and being placed beneath buildings, hard surfacing, or an adequate thickness (at least 600 mm) of clean cover material.

Total Petroleum Hydrocarbons (TPH)

TPH were tested for in soils routinely across the Phase 1 area. It should be noted, however, that at locations where TPH risk is likely to be higher (e.g. Pingemead Industrial Estate), there is no recent soil testing data available; the ground conditions tested may not, therefore, accurately represent current ground conditions.

The majority of the testing undertaken was for total TPH, without speciation by carbon chain length or by aliphatic/aromatic type. In some instances, the TPH tested for comprised only the diesel range organics (DRO) or extractable petroleum hydrocarbons (EPH) taken as carbon chain lengths C10-40. Where fully speciated testing was undertaken, accurate comparisons can be made to the GAC, and no recorded exceedances were identified.

Where fully speciated testing was not undertaken, the recorded concentrations have been compared to the most conservative of the relevant TPH fractions listed within the Ramboll GAC. This represents a highly conservative approach. Where exceedances of the GAC occur, these concentrations are considered to be *potentially* elevated.

Potentially elevated concentrations of TPH occur in the Phase 1 area. The potentially elevated TPH was recorded at the locations provided in Table 8, with all those over 60 mg/kg being within the area of Pingemead Industrial Estate.

Table 8 Potentially Elevated Concentrations of TPH in Soils: Phase 1

ID	Description	Depth of Sample (m bgl)	Concentration (mg/kg)	Strata
TP202	Mineral oil/paraffin	0.25	62	Topsoil / Alluvium
TP103	EPH	0.17	60	Made Ground
TP104	EPH	2.3-2.7	50	Alluvium
TP108	EPH	0-2.2	34	Made Ground
TP224	EPH	2.5	187	Made Ground
WS5_2002	DRO	0.5	338	Made Ground
WS08/01	EPH	0.4	120	Made Ground
WS08/06	EPH	0.3	290	No log available
WS08/08	EPH	0.5	95	No log available
WS08/09	EPH	0.5	310	No log available

Within 5 m of the Phase 1 boundary, to the south, TPH was also recorded at:

- i. TPA03, 130 mg/kg 0.3 m bgl in topsoil

The occurrences of potentially elevated TPH outside of the area of Pingemead Industrial Estate are unlikely to be of significance. This is due to the GAC for individual TPH banded ranges with carbon chain lengths greater than C10 all being greater than 60 mg/kg. (see Figure 19).

No potentially elevated TPH was recorded elsewhere in the Phase 1 area; however, investigations at the Pingemead Industrial Estate were not specifically targeted to potential sources, such as beneath fuel storage tanks.

No BTEX (benzene, toluene, ethylbenzene and xylenes) and no MTBE (methyl-tert butyl ether) were identified at elevated concentrations within the Phase 1 area.

Polycyclic Aromatic Hydrocarbons (PAHs)

Assessment of PAHs has been undertaken utilising the Category 4 Screening Level (C4SL) surrogate marker approach for benzo(a)pyrene.

PAHs comprise a range of substances, for which testing is typically undertaken for a suite of 16 PAHs known as the United States Environmental Protection Agency (USEPA) suite. The USEPA 16 PAHs are considered to be the more common PAHs identified on land affected by contamination.

The testing undertaken at Phase 1 incorporated a 'PAH screen' in 2002, and speciated USEPA 16 PAHs in subsequent investigations.

From the speciated USEPA 16 PAH datasets, none of the recorded concentrations exceed the GAC. The concentrations recorded from 'PAH screen' analysis have been compared to the most conservative GAC. One potentially elevated concentration of PAH, 62 mg/kg, was recorded in the southwest corner of the Phase 1 area at TP202 in topsoil / Alluvium at 0.25 m depth. By consideration of other data for the sum of individual PAH species determined from speciated analysis, the concentration of PAHs recorded at TP202 was the highest recorded total PAH concentration within the Phase 1 area.

Given that the recorded concentration at TP202 relates to a PAH screen, and based upon the distribution of individual PAH species which were identified elsewhere at the site, it is likely that the GAC for benzo(a)pyrene would be exceeded (at TP202 only) (see Figures 17 and 18).

Due to the proposal to raise site levels across this area of the site by over a metre, any pollutant linkage to end users would be mitigated by the development design. The Made Ground from the industrial estate area would not however be likely to be suitable for reuse elsewhere within the site unless deemed appropriate through specific testing and being placed beneath buildings, hard surfacing, or an adequate thickness (at least 600 mm) of clean cover material.

Other Semi-volatile Organic Compounds (SVOCs) and Phthalates

Other SVOCs and phthalates were tested for at WS08/03, WS08/06, WS08/08 and WS08/09. No elevated concentrations of other SVOCs were identified in any of the samples tested. All results were below the laboratory detection limit of 0.1 mg/kg.

Volatile Organic Compounds (VOCs)

VOCs were tested for at WS08/03, WS08/06, WS08/08 and WS08/09. No elevated concentrations were recorded; all results were below the laboratory detection limits.

It should be noted however that chlorinated solvents were identified in groundwater at WS08/01 and WS08/05. No soil testing for chlorinated solvents was undertaken at these locations.

Asbestos

Asbestos has not been identified in soils at any of the tested locations within the Phase 1 area, although only three samples of shallow Made Ground were screened for the presence of asbestos. There may be asbestos present within the existing buildings and structures at Pingmead Industrial Estate, and as such there is also potential for fibre release during the demolition phase.

No asbestos was tested for from the soil stockpiles within the Phase 1A area (see Figure 12). Within 5 m of the Phase 1 area, at the south eastern corner of the Pingmead Industrial Estate, suspected ACM was found at TPA02 (sheeting). Testing results confirmed chrysotile to be present.

5.4.2 Soil Results – Groundwater Risk Assessment

Assessment of risks to groundwater from results of soil testing has been made by:

- i. Review of potential for the presence of free phase product at the site; and
- ii. Review of soil leachate data to assess the likelihood of potential contaminants in soils leaching to groundwater.

Free Phase

The potential for free phase hydrocarbons can be identified from the soil testing data where the recorded concentrations exceed theoretical soil saturation limits. However, due to the nature of testing undertaken for non-speciated TPH, it is not pragmatic to utilise this data to assess theoretical risks of the presence of free phase hydrocarbons.

Potential free phase aliphatic hydrocarbons with carbon chain lengths greater than C16 have been identified in the area of Pingmead Industrial Estate (WS08/03, WS08/04), near to the locations of known former fuel storage tanks and/or cess pits. The soil logs for WS08/03 and WS08/04 did not however record any visual or olfactory evidence for contamination, and it is therefore considered unlikely that the theoretical risk from free product would arise at these locations.

Soil Leachate

Soil leachate results have been assessed by comparison to Ramboll's GAC for waters (see Appendix 2). The available leachate testing data comprises that from shallow soils in the upper 1.1 m bgl, including:

- i. Waste acceptance criteria (WAC) testing undertaken by PBA (2009) at WS08/01, WS08/03, WS08/06, WS08/08, and WS08/09 (metals, sulphate, PAHs and EPH); and
- ii. Leachate data acquired by PBA (2015) for TP101, TP105, TP112 and TP113 (metals, sulphate and EPH), these samples were acquired from soil stockpiles on site which have been placed in the Phase 1A East area.

Cadmium

A single occurrence of elevated cadmium concentration in leachate of 1.5 µg/l was recorded at WS08/09, which exceeds the GAC of 0.08 µg/l. No cadmium was identified in any of the other leachate samples analysed, and the exceedance is therefore isolated in nature.

The isolated exceedance occurs beneath an area which is proposed for building and hard standing, and it is therefore unlikely that leaching from of cadmium from soils at WS08/09 would occur once the proposed development is constructed.

Chromium

Elevated concentrations of chromium in leachate were identified at TP101, WS08/06, and WS08/08. The maximum recorded concentration of 5 µg/l which occurred at WS08/06, and WS08/08 only slightly exceeds the GAC of 4.7 µg/l.

Given that the exceedances of the GAC are small, and that leachate analysis over-estimates the actual leachability of substances from soils due to the analytical methods used, the recorded chromium concentrations are not considered to be of concern.

Vanadium

Vanadium was identified in leachate at 70 µg/l at WS08/03, higher than the GAC of 20 µg/l. All other concentrations of vanadium in leachate were recorded below the GAC.

Given that, the occurrence of elevated vanadium in leachate is isolated, and that leachate analysis over-estimates the actual leachability of substances from soils due to the analytical methods used, the recorded vanadium concentrations are not considered to be of concern.

Nitrates and Phosphates

No elevated concentrations of nitrates or phosphates were identified in any of the leachate samples tested.

TPH

It should be noted that during the leachate extraction process, volatile fractions of hydrocarbons may be lost.

Hydrocarbons were recorded in leachate at concentrations in excess of the GAC of 10 µg/l at TP101, TP105, TP112, TP113, WS08/03 and WS08/09. The concentrations at these locations ranged between 60 µg/l and 180 µg/l.

Given that the recorded concentrations exceeded the GAC in six out of nine samples tested, and the exceedances were between six and eighteen times higher than the GAC, the potential for leaching of hydrocarbons from soils is considered to be significant.

PAHs

None of the recorded concentrations of PAHs in leachate exceed the GAC. However, it should be noted that no PAH in leachate testing was undertaken at TP202 where the highest levels of PAHs in soils were recorded.

5.4.3 Groundwater Results

Groundwater analytical results have been compared to Ramboll GAC (see Appendix 2). Some of the GAC are dependent upon water hardness, a measure of which (as alkalinity) was made by PBA in July 2007 (see references in Table 5). Based upon a conservative 5th percentile of the mean concentrations at each of the positions monitored in 2007 for alkalinity, typical hardness values have been derived as shown in Table 9. These apply across the whole of the site.

Table 9 Typical Hardness Values Applied to Ramboll Assessment

	Surface Water	Made Ground	Lambeth Group	Chalk
Alkalinity mg/l CaCO₃	235	240	260	280

Hardness values are noted to vary between the geological strata. For simplicity, assessments have been made utilising a typical hardness range of > 200 mg/l to < 250 mg/l for all strata at the GPV site.

Previous assessments have relied upon the Alluvium at the site preventing contamination from the Made Ground from affecting the underlying Secondary Aquifers of the River Terrace Deposits and Lambeth Group. However, from review of all of the available data, Ramboll has found that the Alluvium is not continuously present across the site, and therefore cannot be relied upon in this regard. Furthermore, the proposed development may require foundations and service routes which pass from the Made Ground through the Alluvium, and into the Secondary Aquifers, potentially introducing contaminant pathways.

Groundwater flow is expected to be towards the northeast in the Made Ground and River Terrace Deposits, and towards the east or southeast in the Lambeth Group and the Chalk Group.

Metals and Metalloids and Other Inorganics

Copper

Concentrations of copper were recorded in groundwater in 2008 between 3.8 µg/l and 8.6 µg/l within the area of Pingemead Industrial Estate.. Based upon groundwater alkalinity data, the GAC is not exceeded for the recorded water hardness and thus the concentrations are not considered to be of concern (see Figure 23).

A further isolated occurrence of copper was recorded in 2002 at BH105 at 38 µg/l in the Chalk groundwater.

Chromium

Slightly elevated concentrations of chromium were recorded at 4 µg/l to 5 µg/l in groundwater of both the Chalk and more shallow strata within the area of Pingemead Industrial Estate (WS08/06, WS08/08 and WS08/09). The chromium recorded is unlikely to relate to hexavalent chromium, and therefore is only marginally above the GAC for chromium III of 4.7 µg/l . As there are no logs available for these boreholes, the groundwater body to which the results relate is not known, but would arise from groundwater less than 4.5 mbgl as none of the WS08 boreholes were extended beyond this depth (see Figure 22).

A further isolated occurrence of chromium was recorded in 2005 at BH105 at 12 µg/l in the Chalk groundwater.

Manganese

A single isolated occurrence of manganese was recorded from groundwater sampling during the period 2002 to 2005 at BH105 in the Chalk groundwater. Concentrations ranged between 90 µg/l and 219 µg/l, consistently exceeding the GAC of 30 µg/l (see Figure 26).

Other Metals and Metalloids

No other metals or metalloids were identified in groundwater within the Phase 1 area at concentrations in excess of the relevant GAC.

Ammonia

A single isolated occurrence of ammonia was recorded from groundwater sampling during the period 2002 to 2007 at BH105 in the Chalk groundwater. Concentrations ranged between 900 µg/l and 1700 µg/l, consistently exceeding the GAC of 300 µg/l.

No other inorganics were identified in groundwater in the Phase 1 area at concentrations in excess of the GAC (see Figure 20).

Summary

The only elevated concentrations of inorganics identified in groundwater beneath the Phase 1 area comprise copper, chromium, manganese and ammonia in the Chalk at BH105. The well sampled water from a depth of 20 m bgl to 25 m bgl. This borehole is located at the eastern boundary of the Phase 1 area, approximately 30 m north of a surface water drainage channel, although the groundwater within Chalk is not likely to be in hydraulic continuity with the drainage channel.

There is no known source within the GPV site for the contamination identified, and given the depth at which it occurs, it is not anticipated to pose a risk to health. The proposed development would not present any new pathway for contaminant migration as it is already within the Chalk, and no new sources will be introduced. As such, no further actions are recommended to address the potential contamination identified at BH105.

Bacteriological

No bacteria were identified in groundwater at the Phase 1 area. However, cess pits such as those at the Pingemead Industrial Estate could represent a source area for such contamination and were not specifically targeted for testing for bacteriological analysis (see Figure 37).

Phenols

No elevated concentrations of phenols in excess of the GAC were identified in groundwater in the Phase 1 area (see Figure 34).

Polycyclic Aromatic Hydrocarbons (PAHs)

Potentially elevated PAHs in excess of 0.02 µg/l have been identified in groundwater in the area of Pingemead Industrial Estate at WS08/01 (Alluvium and River Terrace Deposits), WS08/06 and WS08/09. Due to the absence of logs for WS08/06 and WS08/09 the groundwater body sampled is not known (see Figure 32).

Specific PAHs identified however comprise fluoranthene and benzo(a)pyrene, and the concentrations recorded do not exceed the specific GAC for these particular PAHs. As such, the recorded concentrations are not considered to be significant.

Total Petroleum Hydrocarbons (TPH)

TPH were identified in groundwater at four locations within the Phase 1 area in excess of the GAC of 10 µg/l.

Within the area of Pingemead Industrial Estate, elevated concentrations of TPH as DRO (C10-40) were recorded at three locations, WS08/03, WS08/05 and WS08/06. The concentrations ranged between 13 µg/l and 100 µg/l. Leachate testing data indicates that the presence of TPH in groundwater may arise from leaching of TPH from soils (see Figure 33).

The locations at which the TPH were recorded include locations adjacent to the north-south trending surface water ditch, and a location within approximately 25 m of the lake.

It is noted that low concentrations of benzene, toluene, ethylbenzene and xylene (BTEX) compounds were identified in groundwater. This suggests that the TPH in groundwater may not be solely composed of the C10-40 fraction which was previously tested for.

Elevated total TPH concentrations were also recorded in 2002 at BH105 in groundwater of the Chalk. There is no known specific source for TPH in the Chalk groundwater at this location. The recorded concentration of 2000 µg/l was identified using infra-red (IR) methods. IR methods are prone to interferences from non-petroleum sources, and the TPH identified could relate to other organic substances. This result should therefore be treated with caution as it is not likely to represent an existing risk.

Chlorinated Solvents

Chlorinated solvents were identified in shallow groundwater of the Alluvium and River Terrace Deposits at WS08/01 and WS08/05 from sampling undertaken in 2008. The solvents identified included 1,1-dichloroethane at concentrations of up to 11 µg/l and cis-1,2-dichloroethene at concentrations of up to 3 µg/l. The solvents are likely to have arisen from the use of e.g. degreasers or thinners at the former metal fabricators and/or vehicle maintenance operations.

Cis-1,2-dichloroethene is a breakdown product of other chlorinated solvents (perchloroethene and trichloroethene), neither of which were identified. It in turn can break down to form the more toxic substance vinyl chloride, for which the current GAC is particularly low at 0.5 µg/l. Consideration should be given to the potential for vinyl chloride to be present in groundwater both currently and in the future as degradation occurs.

The 1,1-dichloroethane concentration of 11 µg/l significantly exceeds the current Water Framework Directive (Standards and Classification) Directive (England and Wales) 2015 standard of 0.4 µg/l annual average and 1.4 µg/l maximum allowable concentrations for C10-40 chloroalkanes in surface waters.

The recorded concentrations of chlorinated solvents may pose a risk to ground and surface water bodies in and adjacent to Phase 1. Furthermore, no testing for chlorinated solvents in soils was undertaken at the locations where they were identified in groundwater. There is potential for the solvents to be present also within soils (see Figure 35).

5.4.4 Ground Gas

Potential sources of ground gas in the Phase 1 area include:

- i. Natural sources such as the decay of organic material in Alluvium, typically around 0.5 m thick;
- ii. Natural sources such as dissolution of Chalk;
- iii. Decay of anthropogenic material and plant material (e.g. roots) in Made Ground which has been identified at thicknesses of up to 3.4 m; and
- iv. Degradation of shallow hydrocarbon contamination in soil and/or groundwater.

Ground gas monitoring was successfully undertaken at six locations within the Phase 1 area. There was an additional number of wells installed but these were flooded (i.e. the groundwater elevation was consistently higher than the top of the well screen during monitoring, thus preventing gas ingress to the well). Data from flooded wells has been excluded from this assessment.

All of the six gas monitoring wells are located in the Phase 1A West and Phase 1B areas (WS08/01, WS08/03-06 and WS08/08-09), and each was monitored once on 13 May 2008 only. At the time of monitoring, the weather was described as being dry, very warm and sunny with clear skies, and the atmospheric pressure was relatively high at 1009 mb and falling slowly. Gas monitoring from the depth of any strata affected by hydrocarbons is not known to have been carried out, and the area of

thick Made Ground (more than 4.5 m thick) identified at e.g. TP224 in the eastern part of Phase 1B, was not included (see Figure 40).

Elevated methane concentrations were recorded at WS08/06 at 8.8 % by volume (v/v), and at WS08/08 at 1.4 % v/v. An elevated concentration of carbon dioxide of 5.6 % v/v was recorded at WS08/06. Ground gas flow rates were recorded to be below the detection limit of the analyser used on both occasions. Hydrocarbons were identified in the soil and/or groundwater at both of these locations, and it is feasible that the ground gases identified may relate to either hydrocarbon vapours, or products of the natural decay of hydrocarbons in the ground. No other elevated carbon dioxide or methane concentrations were recorded. Results are summarised in Table 10.

In order to assess the Phase 1A area, an additional six rounds of ground gas monitoring during atmospheric pressures ranging between 1009 mb and 1031 mb, were undertaken by PBA in 2015, including from WS02_2015 located approximately 15 m east of the Phase 1A boundary at which the well response zone encountered 0.4 m thickness of Made Ground. Gas concentrations and flow rates were recorded to be low.

A further six rounds of ground gas monitoring were also undertaken at this time within the Phase 1 West area at WS08/03 and WS08/04. However, by this time the WS08/03 and WS08/04 wells had silted up and groundwater levels were high, such that ground gas entry into the well would be prevented. No additional ground gas monitoring at the wells WS08/06, WS08/08 and WS08/09 was undertaken by PBA in 2015.

Table 10 Summary of Ground Gas Monitoring Phase 1

ID	Response Zone (mbgl)	TPH Recorded in Soils	TPH Recorded in Groundwater	Water Level (m bgl)	Peak Carbon Dioxide (CO ₂) Concentration (% v/v)	Peak Methane (CH ₄) Concentration (% v/v)	Gas Flow Rate (l/hr)	Dates of Monitoring Episodes	Atmospheric Pressure (mb)	Well Response Zone (above groundwater table)
Phase 1A West										
WS08/01	1-4.5 Alluvium and River Terrace Gravel	0.3 mbgl 130 mg/kg 1.0 mbgl 93 mg/kg	100 µg/l	1.54	0.9	<0.1	< LoD	13/05/2008	1009	Alluvium
WS08/03	1-4.5 Alluvium and River Terrace Gravel	0.3 mbgl 130 mg/kg 1.0 mbgl 93 mg/kg	100 µg/l	1.54	0.9	<0.1	< LoD	13/05/2008	1009	Alluvium
WS08/04	1.0-3.7 Alluvium and River Terrace Gravel	0.4 mbgl 180 mg/kg 0.7 mbgl 38 mg/kg	<10 µg/l	1.59	1.2	<0.1	< LoD	13/05/2008	1009	Alluvium
WS08/06	1.00-3.80 Unknown strata due to no available logs	0.3 mbgl 290 mg/kg	100 µg/l	1.66	5.6	8.8	< LoD	13/05/2008	1009	Unknown #
WS08/08	1.00-3.80 Unknown strata due to no available logs	4 mbgl 12 mg/kg	<10 µg/l	1.43	1.1	1.4	< LoD	13/05/2008	1009	Unknown
Phase 1B										
WS08/06	Unknown due to no available logs	0.3 mbgl 290 mg/kg	100 µg/l	1.66	5.6	8.8	< LoD	13/05/2008	1009	Unknown #
WS08/09	1.00-4.30 Unknown strata	0.5 mbgl 310 mg/kg	<10 µg/l	1.51	0.4	0.6	< LoD	13/05/2008	1010	Unknown \$

ID	Response Zone (mbgl)	TPH Recorded in Soils	TPH Recorded in Groundwater	Water Level (m bgl)	Peak Carbon Dioxide (CO ₂) Concentration (% v/v)	Peak Methane (CH ₄) Concentration (% v/v)	Gas Flow Rate (l/hr)	Dates of Monitoring Episodes	Atmospheric Pressure (mb)	Well Response Zone (above groundwater table)
	due to no available logs									

* Note that flooded wells have been excluded. No logs available for WS08/06, WS08/08 or WS08/09 – based upon other WS08 logs, likely to comprise 1m plain pipe from surface with well screen below

Alluvium absent from nearby exploratory holes at WS5 and TP224, response zone likely to comprise Made Ground and River Terrace Deposits

\$ Alluvium present at nearby exploratory hole at WS08/03, response zone may therefore be in Alluvium

From the limited ground gas information available, Phase 1A West and Phase 1B areas are considered to be representative of Characteristic Situation (CS) 2 conditions. This is because although flow rates were low, there is very limited data available and gas concentrations have been recorded above 1% v/v methane and 5% v/v carbon dioxide. The elevated ground gas may arise from degradation of hydrocarbons within the ground (testing for TPH was not carried out at WS08/06 or WS08/08 and therefore a correlation between these cannot be made), from decay of putrescible materials in Made Ground, or via migration of ground gases from gassing sources outside of the site (e.g. landfills) via permeable strata such as River Terrace Deposits which are above the groundwater table at the site.

Assessment of ground gas conditions in the Phase 1A East area was made by PBA in 2015 (Green Park Village – Report on Ground Investigation for Phase 1A ref 30158 rev0), from which the site was classified as an NHBC Green site under the 'traffic light system', and therefore PBA concluded that gas protection measures would not be required. It is understood that this assessment has been agreed by the Local Planning Authority. In accordance with BS8485:2015, designers using the NHBC traffic light system must refer to NHBC and RSK (2007) Guidance on Evaluation of Development Proposals on Sites Where Methane and Carbon Dioxide are Present to assess compliance for specific recommendations.

5.6 Uncertainties and Gaps in the Information

There has been limited asbestos testing undertaken from shallow soils in the Phase 1 area. Of particular concern with this regard is the area of Pingemead Industrial Estate, at which asbestos would be more likely to occur, potentially arising from former buildings/structures, insulation materials and from specific activities at the industrial estate such as vehicle repairs. Risks to health, particularly during the construction phase, may be present. Furthermore, if soils are to re-used on site the presence of asbestos may affect the suitability of the material for re-use. Further testing for asbestos within the upper Made Ground is recommended at Pingemead Industrial Estate, including an allowance for some post-demolition screening of soils.

Within the area of Pingemead Industrial Estate, potential risks from TPH in soils and groundwater have been identified. Due to the nature of the majority of the testing undertaken, comparison to GAC for soils may be over-conservative. Further testing for TPH in soils and groundwater with aliphatic and aromatic banded carbon chain lengths is required at the industrial estate; this should include for testing which is specifically targeted to potential hydrocarbon sources at the site (e.g. current and former oil storage tanks), which to date has not been undertaken.

The distribution of chlorinated solvents, which have been identified in groundwater, is poorly understood, and further testing is required to assess this.

The cause of apparent contamination at BH105 in groundwater of the Chalk is unclear as there is no known specific source of pollution in this part of the Phase 1 area. Although there are uncertainties surrounding the water quality at BH105, further actions are not recommended owing to the depth of the groundwater which has been affected and that the proposed development would not be anticipated to result in deterioration of water quality.

There has been limited investigation of the earth bund which contains waste materials located at the western boundary of the Phase 1 area, and of soils beneath buildings and possible point sources of contamination at Pingemead Industrial Estate. No sampling from the drainage ditches which run north-south through the Phase 1 area, and along the southernmost boundary have been undertaken to date. Further investigation is therefore required in these areas.

The level of gas monitoring undertaken to date is not sufficient to comply with current British Standards and UK specific guidance. The conditions under which monitoring was undertaken are not representative of 'worst case' conditions for gas generation and flow, and may therefore underestimate worst case conditions. Furthermore, logs for the monitored wells are missing for WS08/06, WS08/08 and WS08/09 and therefore the geological strata from which the ground gases have arisen cannot be identified.

PBA has determined that no ground gas protection measures are required within the Phase 1A East area. Based upon their findings, further assessment of ground gases ought to not therefore be required for this part of the Phase 1 area.

Within Phase 1A West and Phase 1B, there is insufficient gas monitoring data to ascertain the gassing regime, and further monitoring is required to clarify this. The design of the proposed development may result in changes to the gassing regime as a result of inducing lateral gas migration, and encouraging gas generation due to loading of the site when site levels are raised. As such, the design of any remedial system will need to account for potential changes to the gas regime, and monitoring will need to continue through the construction phase.

Much of the testing undertaken within the study area was acquired some time ago, and since this time ground conditions may have changed. This is of particular concern at Pingemead Industrial Estate where the industrial units have seen various uses by different occupiers during the period since investigations began.

5.7 Risk Evaluation and Conceptual Model

The elevated lead, chromium and PAH concentrations recorded at Pingemead Industrial Estate, together with potential asbestos, would be unlikely to pose a risk to human health of end users given that ground levels are proposed to be raised by approximately 1.35 m in the affected area.

Made Ground soils excavated from the area of the Pingemead Industrial Estate would not however be suitable for re-use within residential gardens or areas of soft landscaping unless covered by a suitable clean soil capping, but subject to leachate testing may be suitable for use elsewhere on site. Control of the release of any substances from excavated Made Ground soils would be required, and could be mitigated by suitable site construction practices. Risks to construction workers would similarly be mitigated by suitable site construction practices in addition to use of standard construction Personal Protective Equipment (PPE).

Potential risks from TPH and chlorinated solvents in soils and groundwater at Pingemead Industrial Estate to underlying aquifers and nearby surface water bodies (ditches and the Trout Lakes within the GPV site) have been identified. These potential risks should be further considered in the context of detailed quantitative risk assessment in order to ascertain whether the potential risks are likely to be realised, and if required, to derive remedial targets.

The existing ditch on site is not shown on plans of the proposed development. If this ditch is in-filled, the existing water within the ditch will require removal, appropriate disposal and alternative drainage will need be provided. Particular care will be required to ascertain that fill material placed within the watercourse will not pose a risk of leaching of contaminants.

The qualitative hazard assessment identifying potential pollutant linkages has been undertaken below using the source-pathway-receptor framework detailed in Appendix 1. An assessment of the potential significance of each linkage has been made by consideration of the likely magnitude and mobility of the source, the sensitivity of the receptor and nature of the migration/exposure pathways.

Table 11 Phase 1 Conceptual Site Model

Potential Source	Potential Contaminant(s)	Pathway	Potential Receptor	Probability of Risk Being Realised*	Consequence of Risk Being Realised*	Risk Classification*
Made Ground at Pingemead Industrial Estate (including bund on western boundary, within the Phase 1B area)	Asbestos in soils	Inhalation of released fibres	Construction workers	Low likelihood	Severe	Moderate
			Adjacent site and phase users	Unlikely	Severe	Moderate/low
	Lead, chromium and PAHs in soils	Dermal contact	Construction workers	Likely	Minor	Low
		Inhalation of soil dust	Construction workers	Likely	Mild	Moderate/low
			Adjacent site and phase users	Low likelihood	Mild	Low
		Ingestion of soil	Construction workers	Low likelihood	Mild	Low
	TPH in soil Possible chlorinated solvents in soil	Dermal contact	Construction workers	Likely	Mild	Moderate/low
		Inhalation of soil dust	Construction workers	Likely	Mild	Moderate/low
			Adjacent site and phase users	Low likelihood	Mild	Low
		Ingestion of soil	Construction workers	Likely	Mild	Moderate/low
		Inhalation of vapours	Construction workers	Low likelihood	Mild	Low
			Adjacent site and phase users	Unlikely	Mild	Very low
			Future site users	Low likelihood	Medium	Moderate/low
	TPH in soil and/or groundwater (including potential free phase)	Leaching to groundwater and migration in groundwater	Secondary Aquifers (River Terrace Deposits and Lambeth Group)	Likely	Medium	Moderate
			Principal Aquifer (Chalk)	Low likelihood	Mild (not within a groundwater source protection zone)	Low
			Surface water – Trout Lakes and ditches	Likely	Medium	Moderate
	TPH and potential chlorinated solvents in soil and/or groundwater (including potential free phase)	Permeation of buried water service pipes	Future site users	Unlikely (providing pipes are laid in clean cover material to be placed over the Made Ground)	Medium	Low

Potential Source	Potential Contaminant(s)	Pathway	Potential Receptor	Probability of Risk Being Realised*	Consequence of Risk Being Realised*	Risk Classification*
Shallow groundwater in Alluvium and River Terrace Deposits at Pingemead Industrial Estate	Chlorinated solvents in groundwater	Migration in groundwater, including vertical pathway creation via foundations from shallow to deeper aquifers	Secondary Aquifers (River Terrace Deposits and Lambeth Group)	Likely	Medium	Moderate
			Principal Aquifer (Chalk)	Low likelihood	Mild (not within a groundwater source protection zone)	Low
			Surface water – Trout Lakes and ditches	Low likelihood	Medium	Moderate/low
		Vapour inhalation	Construction workers	Low likelihood	Mild	Low
		Vapour inhalation	Future site users	Low likelihood	Medium	Moderate/low
Groundwater in the Chalk at BH105	Copper and chromium	Migration in groundwater	Principal Aquifer (Chalk)	Likely	Mild (not within a groundwater source protection zone)	Moderate/low
Hydrocarbons, Made Ground, Alluvium and Chalk in Phase 1A West and Phase 1B	Ground gases	Migration of gases and build up in confined spaces	Construction workers	Low likelihood	Medium	Moderate/low
			Future site users	Likely	Medium	Moderate
			Building structures	Likely	Medium	Moderate
		Lateral gas migration caused by development design	Adjacent site and phase users	Low likelihood	Medium	Moderate/low
			Adjacent building structures	Low likelihood	Medium	Moderate/low
Made Ground, Alluvium and Chalk in Phase 1A East*	Ground gases	Migration of gases and build up in confined spaces	Construction workers	Unlikely	Medium	Low*
			Future site users	Low likelihood	Medium	Moderate/low*
			Building structures	Low likelihood	Medium	Moderate/low*
		Lateral gas migration caused by development design	Adjacent site and phase users	Unlikely	Medium	Low*
			Adjacent building structures	Unlikely	Medium	Low*

Potential Source	Potential Contaminant(s)	Pathway	Potential Receptor	Probability of Risk Being Realised*	Consequence of Risk Being Realised*	Risk Classification*
Cess pits	Bacteria/pathogens Ammonia Phosphate and nitrates Heavy metals	Dermal contact	Construction workers	Unlikely	Mild	Very low
		Inhalation of soil dust	Construction workers	Unlikely	Mild	Very low
			Adjacent site and phase users	Unlikely	Mild	Very low
		Ingestion of soil	Construction workers	Low likelihood	Mild	Low
		Migration in groundwater	Secondary Aquifers (River Terrace Deposits and Lambeth Group)	Low likelihood	Mild	Low
			Principal Aquifer (Chalk)	Unlikely	Mild	Very low
			Surface water – Trout Lakes and ditches	Low likelihood	Medium	Moderate/low
Diffuse, regional groundwater contamination	Ammonia and manganese	Vertical and lateral migration via permeable strata	Secondary Aquifers (River Terrace Deposits and Lambeth Group)	Low likelihood	Mild	Low
			Principal Aquifer (Chalk)	Low likelihood	Mild	Low

Note All risks assume no mitigation in place - for definition of terms see Appendix 1 (Assessment Criteria) * Based upon PBA 2015 assessment of gas monitoring data only

5.8 Conclusions

The Phase 1 site has been divided along the line of a north-south trending ditch into an east and a west area. It is necessary to raise ground levels to 40.25 mAOD across the whole of the Phase 1 area. Phase 1A West and Phase 1B are currently occupied by a derelict industrial estate, and Phase 1A East has been subject to land raising by utilisation of soil stockpile materials from the Phase 1 and wider 'Eastern Triangle' area of the site. Housing construction at Phase 1A East is currently underway.

The Phase 1A East area is understood to have been assessed by PBA (2015), for which no potential significant pollutant linkages were identified. Based upon the PBA assessment, no further assessment of risk is required at Phase 1A East.

A number of potential pollutant linkages are present at Phase 1A West and Phase 1B, which will require further investigation and risk assessment to determine whether any remedial measures are required. These include the following risks:

- i. Asbestos in Made Ground, for which there has been little testing;
- ii. Bacteria/pathogens within soil or groundwater near to cess pits at Pingemead Industrial Estate;
- iii. Hydrocarbons in soil and/or groundwater which may leach and affect water bodies;
- iv. Chlorinated solvents in groundwater of the Secondary Aquifers; and
- v. Ground gases which may build up in confined spaces causing a risk to end users and future building structures.

5.9 Recommendations and Implications for Design, Construction and Project Planning

The existing disused groundwater abstraction well at the Phase 1 area will need to be appropriately decommissioned in line with current Environment Agency guidance. The decommissioning method will need to be agreed by an environmental specialist, and records will need to be maintained for the purposes of validation.

Further ground investigation to ascertain the quality of groundwater and soil (hydrocarbons, chlorinated solvents and asbestos in particular), and the ground gas regime, is required within the area of Phase 1A West and Phase 1B, principally within the area of the Pingemead Industrial Estate. The gas monitoring should include for vapours, and it may be prudent to sample and test ground gas to determine its constituents.

Detailed quantitative risk assessment is likely to be necessary to determine the risks from hydrocarbons in soil and groundwater to water bodies at and adjacent to Phase 1.

Given that site levels are proposed to be raised, gas monitoring would be required to continue following placement of material to raise ground levels. This is necessary to ascertain whether lateral gas migration has been initiated as a result of the development scheme.

Pending the results of additional investigations, allowance should be made for the provision of ground gas protection measures to all buildings within Phase 1A West and Phase 1B.

In the absence of specific testing beneath potential point sources of contamination, the bund containing waste materials and beneath buildings, further investigation is required to be focussed upon these areas. Allowance ought to be made for localised removal of hotspots of soils impacted by contamination. Detailed quantitative risk assessment is likely to be required to assess risks to controlled waters, and localised remediation may be necessary. Depending upon the proposed foundation solution, a piling risk / ground improvement assessment may be required if the solution could introduce pathways for contaminant migration.

Depending upon the findings of supplementary investigations, specific controls for the release of soil dust / asbestos fibres during site works may be required in order to protect ground workers and users of nearby land.

6. ASSESSMENT OF PHASE 1C EAST AND PHASE 2

6.1 Site Setting

Geographically, the area of Phase 1C East is between the individual sections of the Phase 2 areas of the site. Therefore, assessment of the Phase 1C East area has been included with that for Phase 2.

The Phase 2 and Phase 1C East area is situated in the south-central part of the site, and is bounded by the existing Trout Lakes to the west, a ditch at the south easternmost boundary, Smallmead Road to the south, and Phase 1 area to the north and east (see Figure 2).

Phase 2 is subdivided into three parts, Phase 2A, Phase 2B and Phase 2C. Phase 2A is separated from Phases 2B and 2C by a proposed new road (Phase 1C East), and Phases 2B and 2C are separated by Phase 1B. An existing area of land within the site boundary, but excluded from the development phase areas comprises that between the Phase 2A and Phases 2B / 2C proposed for a road, and an area of proposed green space at the south-eastern corner of the Trout Lakes. For the purposes of the assessment, these areas have been discussed as the 'Phase 2 Additional' area.

Land at Phase 2 is predominantly disused, but does include existing disused houses in Phase 2A, one of which was previously used as the GPV site office. Phases 2A and 2C incorporate the access road serving the derelict Pingemead Industrial Estate. Phase 2C incorporates the south eastern corner of Pingemead Industrial Estate which lies on the east side of a north-south trending ditch, and vacant land to the west side of that ditch. Due to the differing former and current land uses at Phase 2B, it has been subdivided into Phase 2B East (east of the north-south trending ditch) and Phase 2B West (west of the north-south trending ditch, i.e. Pingemead Industrial Estate).

The industrial units within Phase 2B West were originally farm buildings, but have since been utilised for a variety of light industrial purposes. These uses include vehicle repairs, bodywork and servicing, and metal fabricators. The industrial estate has various disused above ground oil storage tanks (both existing and historic) and cess pits. A plan showing the potential contaminative uses of the industrial estate is provided in Figure 3. As detailed in Section 5.1, the general housekeeping within the industrial estate when it was active may have been poor.

The north-south trending ditch which separates the Phase 2 area has been noted by Ramboll consultants during a site visit in January 2015 to be blocked by various waste and debris.

Phase 2B East: The Phase 2B East area to the east of the ditch is currently disused. An area of trees lines the eastern side of the ditch, beyond which is open land. Along the south eastern boundary of the Phase 2B East area is a further tree-lined ditch.

6.2 Proposals for the Phase 1C East and Phase 2 Areas

The Phase 1C East area is proposed for construction of a new road with roundabout, and an area of green open space adjacent to the existing Trout Lakes.

Phase 2A will comprise a new care home facility with associated soft landscaping and car parking in the western portion. In addition an area of residential apartments will be constructed to the west of the care home building, the majority of which will be built over garages.

Phase 2B will comprise a new primary school with sports pitches for dual school and local community use. Community facilities including a community hall are also to be provided.

Residential development is proposed in Phase 2C, comprising a single block of residential units with communal areas of soft landscaping.

Ground levels are to be raised for flood protection purposes. The approximate proposed ground level elevations are as follows:

- Phase 2A: 40.2 mAOD to 40.65 mAOD (1.2m to 1.9 m)
- Phase 2B: 40.5 mAOD to 40.7 mAOD (1.5 m to 2.7 m)
- Phase 2C: 40.4 mAOD to 40.7 mAOD (1.4 m to 1.9 m)
- Phase 1C East: 40.6 mAOD to 40.8 mAOD (1.5 m to 1.9 m)

6.3 Summary of Exploratory Locations in Phase 1C East and Phase 2

Table 12 below provides a summary of exploratory holes advanced within Phase 1 East and Phase 2, including details of monitoring well installations, groundwater strikes and visual/olfactory evidence of contamination. A 5 m buffer zone has been applied to the Phase 1C East and Phase 2 areas to capture all the relevant data adjacent the phase.

Table 12 Summary of Exploratory Locations in Phase 1C East and Phase 2

ID	Depth to Base of Hole (m bgl)	Groundwater Strike (m bgl)	Response Zone (m bgl)	Response Zone Strata	Visual/Olfactory Evidence of Contamination
Phase 1C East					
WS3	4	1.24	1.00 – 3.70	Alluvium and River Terrace Deposits	Bituminous paving, bricks and concrete
TPA03	1.5	0.5	-	-	None
TPA06	1.5	0.2			Organics which consist of natural plant and wood remains in Made Ground. Brick fragments in Made Ground
TPA07	2.5	0.5			Brick fragments in Made Ground
BH106	10.0	0.9	1.0-2.9	River Terrace Deposits	Brick fragments and roots in Made Ground
Phase 2A					
WS1	3	Dry	1.00 - 3.00	Alluvium	None
WS2	3	Dry	-	-	None
TPA05	1.8	0.6	-	-	Occasional wood fragments, flint and organic materials (roots)
Phase 2B					
WS4	4	1.25	1.00 - 4.00	Alluvium and River Terrace Deposits	Bituminous paving material
TP209	2	1.05	-	-	None
WS08/01	4.5	No record	1.00 - 4.50	Alluvium and River Terrace Deposits and Lambeth Group	Fragments of brick, tarmac and clinker
TPA01	2	0.6	-	-	Cobbles of brick, concrete, frequent plastic, metal and ceramics
TPA02	0.5	No record	-	-	Asbestos cement sheeting, brick and clinker
TP109	2.7	2.7	-	-	Stockpile; fragments of bricks, concrete, timber, tree stump, organic material (roots) and noted to be 'very organic'

ID	Depth to Base of Hole (m bgl)	Groundwater Strike (m bgl)	Response Zone (m bgl)	Response Zone Strata	Visual/Olfactory Evidence of Contamination
TP114	1	Dry	-	-	None
WS01_2015	3	0.4	0.16 - 2.00	River Terrace Deposits	None
Contained within the 5 m buffer zone of Phase 2B					
WS08/03	4.1	No record	1.10 - 4.10	Alluvium and River Terrace Deposits and Lambeth Group	Rare fragments of brick
TP108	2.7	Dry	-	-	Stockpile; occasional flint gravel, plastic, tarmacadam, concrete cobbles, metal fragment, brick fragments and organic materials (roots)
Phase 2C					
TPA04	1.4	0.6	-	-	Occasional brick and concrete

6.4 Evaluation and Assessment of Results

The evaluation and assessment of results is based upon review of the following reports:

- PBA (2002) Geo-environmental Investigation for Phase III, Green Park, Reading WS1-4, TP209;
- PBA (2009) Report on Ground Condition Assessment – Phase 1 and 2. Green Park Station – Temporary Access Road and Park TPA01-3, TPA05-7, WS08/01, WS08/03; and
- PBA (2015) Report on Ground Investigation for Phase 1A. Green Park Village WS01_2015, TP108, TP109, TP114.

6.4.1 Soil Results – Human Health Risk Assessment

As the most conservative end use at the Phase 1C East and Phase 2 area of the site is residential end use with communal gardens, the concentrations of substances in soil have been assessed by comparison to GAC for a residential without plant uptake end use (see Appendix 2).

Testing for a range of metals and metalloids, TPH, PAHs and phenols was routinely undertaken within Phase 1C East and Phase 2 areas from both Made Ground and the natural strata. The majority of samples were obtained from the Made Ground. In selected areas of the site, testing was also undertaken for other semi-volatile organic compounds and volatile organic compounds.

Metals and Metalloids

Chromium

The GAC for hexavalent chromium in a residential setting is 21 mg/kg. Trivalent chromium is the more common and stable form of chromium, for which the GAC is 910 mg/kg.

Concentrations of chromium which are elevated above residential GAC were identified at WS08/01 only (23 mg/kg). This occurred in the upper 0.5 m of Made Ground at Pingemead Industrial at.

Given that the maximum recorded concentration of total chromium is only marginally higher than the GAC for hexavalent chromium, no significant risks from chromium are considered likely to be realised (see Figure 13).

Other Metals and Metalloids

Concentrations of all other metals and metalloids (e.g. lead, mercury, arsenic, cadmium, copper, nickel, selenium and zinc) were all recorded at concentrations below the residential GAC.

Summary

Potentially elevated chromium has been identified in the shallow (up to 0.5 mbgl) Made Ground at one location at Pingemead Industrial Estate when compared to the hexavalent chromium GAC. It is unlikely to relate entirely to hexavalent chromium, and it is therefore unlikely that any risks to health would arise from this single potentially elevated result. Due to the proposal to raise site levels across this area of the site by over a metre, any pollutant linkage to end users would be mitigated by the development design.

The Made Ground from the industrial estate area would not however be likely to be suitable for reuse elsewhere within the site unless deemed appropriate through specific testing and being placed beneath buildings, hard surfacing, or an adequate thickness (at least 600 mm) of clean cover material.

Total Petroleum Hydrocarbons (TPH)

A total of six samples from shallow Made Ground (0 to 0.5 mbgl) and one from deep Made Ground (over 1 mbgl) were tested for TPH, including at the following locations:

- Phase 2B West: WS08/01 in shallow Made Ground;
- Phase 2B East: TP209 in shallow topsoil/Alluvium, WS01_2015 in shallow Made Ground, TP109 in deep Made Ground, TP108 in shallow Made Ground;
- and
- Phase 1C East: TPA03 in shallow Made Ground, TPA07 in shallow Made Ground

The majority of the testing undertaken was for total TPH in the EPH range carbon chain lengths C10-40, without speciation by carbon chain length or by aliphatic/aromatic type, and the maximum recorded concentration was 130 mg/kg. TPH was identified at the locations shown in Table 13 (see Figure 19).

Table 13 Concentrations of TPH Recorded in Soils: Phase 2 and Phase 1C East

Phase	ID	Description	Depth of Sample (m bgl)	Concentration (mg/kg)	Strata
Phase 1C East	TPA03	EPH	0.3	130	Made Ground
	TPA07	EPH	0.5	110	Made Ground
Phase 2B West	WS08/01	EPH	0.4	120	Made Ground
Phase 2B East	TP209	EPH	0.3	11	Made Ground
	TP109	EPH	1.3	<10	Made Ground
	WS01_2015	EPH	0.3-0.45	<10	Made Ground
Within 5 m of Phase 2B	TP108	EPH	0-2.2	34	Topsoil

Where fully speciated testing was not undertaken, the recorded concentrations have been compared to the most conservative of the relevant TPH fractions listed within the Ramboll GAC. This represents a highly conservative approach, and where such exceedances occur these concentrations are considered to be *potentially* elevated.

None of the recorded concentrations exceed the GAC for a residential use without home-grown produce, however there has only been a small number of soil samples tested for TPH. No results are available from the area of an above ground oil tank at the southeast corner of industrial buildings in Phase 2B West. Further testing for TPH would be necessary to fill in data gaps.

Polycyclic Aromatic Hydrocarbons (PAHs)

The testing undertaken at Phase 1C East and Phase 2 incorporated a 'PAH screen' in 2002, and speciated USEPA 16 PAHs in subsequent investigations.

A total of seven samples from shallow Made Ground (0 to 0.5 mbgl) and one from deep Made Ground (over 1 mbgl) were tested for, including at the following locations:

- Phase 2B West: WS08/01 in shallow Made Ground;
- Phase 2B East: TP209 in shallow topsoil/Alluvium, WS01_2015 in shallow Made Ground, TP109 in deep Made Ground, TP108 in shallow Made Ground;
- and
- Phase 1C East: TPA03 in shallow Made Ground, TPA07 in shallow Made Ground.

From the speciated USEPA 16 PAH datasets, none of the recorded concentrations exceed the GAC. The concentrations recorded from 'PAH screen' analysis have been compared to the most conservative GAC. One potentially elevated concentration of PAH, 29 mg/kg, was at TP209 in topsoil / Alluvium at 0.3 m depth. No other potentially elevated concentrations of PAHs were identified. It is possible that the GAC for individual PAH species may be exceeded at TP209.

Due to the proposal to raise levels across this area of the site by over a metre, any pollutant linkage to end users would be mitigated by the development design. The Made Ground and shallow alluvium/topsoil would not however be likely to be suitable for reuse elsewhere within the site unless deemed appropriate by specific testing and placed beneath buildings, hard surfacing, or an adequate thickness (at least 600 mm) of clean cover material (see Figures 17 and 18).

Further testing for PAHs is required to fill in data gaps.

Other Semi-volatile Organic Compounds (SVOCs) and Phthalates

Other SVOCs have not been routinely tested for in Phase 1C East and Phase 2.

6.4.2 Volatile Organic Compounds (VOCs)

VOCs have not been routinely tested for in Phase 1C East and Phase 2.

Asbestos

Suspected ACM was found at TPA02 (sheeting), in the yard area to the south of industrial buildings at Pingemead Industrial Estate. Testing results confirmed chrysotile to be present. There may be asbestos present within the existing buildings and structures at Pingemead Industrial Estate, and as such there is also potential for fibre release during the demolition phase.

Asbestos has not been identified in soils at any of the other tested locations within the Phase 1C East and Phase 2 areas, although only three samples of shallow Made Ground were screened for the presence of asbestos (see Figure 12).

6.5.1. Soil Results – Groundwater Risk Assessment

Assessment of risks to groundwater from results of soil testing has been made by:

- i. Review of potential for the presence of free phase product at the site; and
- ii. Review of soil leachate data to assess the likelihood of potential contaminants in soils leaching to groundwater.

Free Phase

The potential for free phase hydrocarbons can be identified from the soil testing data where the recorded concentrations exceed theoretical soil saturation limits. Due to the nature of testing

undertaken for non-speciated TPH, it is not pragmatic to utilise this data to assess theoretical risks of the presence of free phase hydrocarbons.

Potential free phase aliphatic hydrocarbons with carbon chain lengths greater than C16 have been identified at WS08/03 in groundwater. The soil log at this location did not however record any visual or olfactory evidence for contamination, and it is therefore considered unlikely that the theoretical risk from free product would arise.

Soil Leachate

Soil leachate results have been assessed by comparison to Ramboll's GAC for waters (see Appendix 2). The available leachate testing data comprises that from shallow soils in the upper 1 mbgl, including:

- i. Waste acceptance criteria (WAC) testing undertaken by PBA (2009) for metals, sulphate, PAHs and EPG at WS08/01 1 mbgl in Made Ground, and WS08/03 1 mbgl in Made Ground.

Metals

Elevated concentrations of chromium were identified at 20 µg/l in both of the above samples. These exceed the GAC of 4.7 µg/l.

Concentrations of iron exceed the GAC of 10 µg/l at both locations, being recorded at 140 µg/l and 220 µg/l respectively.

Manganese was recorded in WS08/01 at 96 µg/l, exceeding the annual average GAC of 30 µg/l, but not the maximum allowable concentration of 300 µg/l. Elevated manganese concentrations were not identified at WS08/03.

TPH

Hydrocarbons were recorded at a concentration of 60 µg/l in leachate at WS08/03. The GAC is 10 µg/l. TPH was not tested for in soils at this location so this occurrence cannot be correlated to a specific occurrence in soils at this location. Elevated concentrations of TPH were not identified in leachate at WS08/01.

Given that the recorded concentrations exceeded the GAC by six times, the potential for leaching of hydrocarbons from soils is considered to be significant.

PAHs

Neither of the recorded concentrations of PAHs exceed the GAC.

6.5.2. Groundwater Results

Groundwater analytical results have been compared to Ramboll GAC (see Appendix 2). The hardness range utilised in the assessments for Phase 1C and Phase 2 are as per those for Phase 1; > 200 mg/l to < 250 mg/l.

Groundwater quality testing was undertaken at:

- Phase 2B West: WS08/01 (Alluvium and River Terrace Deposits, data collected in 2008);
- Phase 2B East: WS08/03 within 5 m north of Phase 2B East (Alluvium and River Terrace Deposits, data collected in 2008);and
- Phase 1C East: BH106 (Made Ground and River Terrace Deposits, data collected in 2005 and 2007).

The available groundwater testing data relates to one well in Phase 2 and one near to Phase 2, both of which contained response zone in Alluvium and River Terrace Deposits and one well in Phase 1C with a response zone in Made Ground and River Terrace Deposits. No recent groundwater testing data is available.

Metals and Metalloids, and Other Inorganics

Copper

Concentrations of copper of 4 µg/l at WS08/01 and 3.6 µg/l at WS08/03 were recorded within the area of Pingemead Industrial Estate in 2008. These are not considered to be of concern as based upon groundwater alkalinity data, the GAC is not exceeded. No other copper has been identified in groundwater (see Figure 23).

Chromium

An elevated concentration of 16 µg/l of chromium was recorded at in groundwater in Made Ground / River Terrace Deposits at BH106, and exceeds the GAC of 4.7 µg/l trivalent chromium and 3.4 µg/l hexavalent chromium (see Figure 22).

Manganese

Persistently elevated concentrations of manganese were recorded at up to 246 µg/l in groundwater in Made Ground / River Terrace Deposits at BH106, and exceed the GAC of 30 µg/l. This occurrence is isolated in nature, in that it occurs at BH106 only (See Figure 26).

Nickel

One elevated concentration of 23 µg/l of nickel was recorded in groundwater in Made Ground / River Terrace Deposits at BH106, and very slightly exceeds the GAC of 20 µg/l. This occurrence is isolated in nature, in that it occurs at BH106 only, and only occurred in one of the four rounds of monitoring undertaken (see Figure 28).

Other Metals and Metalloids

No other metals or metalloids were identified in groundwater at the Phase 1C and Phase 2 areas at concentrations in excess of the GAC.

Ammonia

Persistently elevated concentrations of ammonia were recorded at up to 800 µg/l in groundwater in Made Ground / River Terrace Deposits at BH106, and exceed the GAC of 300 µg/l. This occurrence is isolated in nature, in that it occurs at BH106 only (see Figure 20).

No other inorganics were identified in groundwater at the Phase 1C and Phase 2 areas at concentrations in excess of the GAC.

Summary

Persistently elevated concentrations of inorganics (in particular chromium, ammonia and manganese) have been identified at BH106 in the Made Ground / Alluvium. Review of data from the wider site indicates that these elevated concentrations appear to be typical of the wider area.

There is no known source within the site for the elevated inorganic substances identified at BH106, and the potential contamination is anticipated to be diffuse in nature. The proposed development would not present any new pathway for contaminant migration as the only location affected, BH106 is located in an area of proposed road at which ground levels will be raised but foundations would not be required. As such, no further actions are recommended to address the potential contamination identified at BH106.

Bacteriological

No bacteria were identified in groundwater at the Phase 1C and Phase 2 areas. However, cess pits such as those at the Pingemead Industrial Estate (Phase 2B West) could represent a source area for such contamination (see Figure 37).

Phenols

No elevated concentrations of phenols were identified in groundwater at the Phase 1C East and Phase 2 areas which were in excess of the GAC (see Figure 34).

Polycyclic Aromatic Hydrocarbons (PAHs)

Potentially elevated concentrations of PAHs in excess of 0.02 µg/l have been identified in groundwater in the area of Pingemead Industrial Estate at WS08/01 (Alluvium and River Terrace Deposits). The PAH concentration recorded, 0.03 µg/l was only marginally higher than the GAC.

Specific PAHs identified, however, comprise fluoranthene and benzo(a)pyrene, and the concentrations recorded do not exceed the specific GAC for these particular PAHs. As such, the recorded concentrations are not considered to be significant (see Figure 32).

PAHs were not identified in groundwater at BH106.

Total Petroleum Hydrocarbons (TPH)

TPH was identified in groundwater from the Alluvium / River Terrace Deposits at 100 µg/l at WS08/03, which significantly exceeds the GAC of 10 µg/l. The recorded concentration may pose a risk to the surface water ditch at Phase 2B West, and to groundwater (see Figure 33).

Chlorinated Solvents

Chlorinated solvents were identified in shallow groundwater of the Alluvium and River Terrace Deposits at WS08/01 from sampling undertaken in 2008. The solvents identified included 1, 1-dichloroethane at concentrations of up to 11 µg/l. The solvents are likely to have arisen from the use of e.g. degreasers or thinners at the former metal fabricators and/or vehicle maintenance operations.

The 1, 1-dichloroethane concentration of 11 µg/l exceeds the current Water Framework Directive (Standards and Classification) Directive (England and Wales) 2015 standard of 0.4 µg/l annual average and 1.4 µg/l maximum allowable concentrations for C10-40 chloroalkanes.

The recorded concentrations of chlorinated solvents may pose a risk to ground and surface water bodies at and adjacent to Phase 2B West. Furthermore, no testing for chlorinated solvents in soils was undertaken at the locations where they were identified in groundwater. There is potential for the solvents to be present also within soils (see Figure 35).

6.5.3. Ground Gas

Potential sources of ground gas at the Phase 1C and Phase 2 areas include:

- i. Natural sources such as the decay of organic material in Alluvium, typically around 0.5 m thick;
- ii. Natural sources such as the dissolution of Chalk;
- iii. Decay of anthropogenic material and plant material (e.g. roots) in Made Ground which has been identified at thicknesses of up to 2.2 m; and
- iv. Degradation of shallow hydrocarbon contamination in soil and/or groundwater.

Ground gas monitoring was successfully undertaken at five locations within the Phase 2 and Phase 1C. There was an additional number of wells installed but these were flooded (i.e. the groundwater elevation was consistently higher than the top of the well screen during monitoring, thus preventing gas ingress to the well). Data from flooded wells has been excluded from this assessment. Monitored wells comprise those detailed in Table 14 (see Figure 40).

Table 14 Wells Monitored for Ground Gas in Phase 1C East and Phase 2

ID	Response Zone (mbgl)	Peak Carbon Dioxide (CO ₂) Concentration (% v/v)	Peak Methane (CH ₄) Concentration (% v/v)	Gas Flow Rate (l/hr)	Dates of Monitoring Episodes	Atmospheric Pressure (mb)
Phase 2A						
WS1	River Terrace Deposits	All < 5 %	All < 1 %	< LoD	May 2002 – May 2006 19 rounds	995-1016
Phase 2B East						
WS01_2015	Alluvium	All < 5 %	All < 1 %	< LoD	February 2015 – April 2015 4 rounds	1009-1037
Phase 2B West						
WS08/01	Alluvium, River Terrace Deposits, Lambeth Group	All < 5 %	All < 1 %	< LoD	May 2008 1 round	1009
WS4	Alluvium, River Terrace Deposits	All < 5 %	All < 1 %	< LoD	May 2002 – June 2002 6 rounds	995-1014
WS08/03 #	Alluvium, River Terrace Deposits	All < 5 %	All < 1 %	< LoD	May 2008 1 round	1009

Gas monitoring data is limited in that:

- No gas monitoring was undertaken from wells with response zones within the Made Ground, which occurs at the site at thicknesses of up to 2.2 m in Phase 2B East, and up to 0.9 m elsewhere within the Phase 2 and Phase 1C study area;
- No gas monitoring was undertaken in Phase 1C East or Phase 2C;
- In Phase 2A (proposed for residential end use) only one well was monitored, and the data relating to that well is not recent;
- In Phase 2B (proposed for school and community facilities), recent data has been collected from one well only; and
- There is insufficient ground gas monitoring data to meet the minimum recommended requirements of current UK ground gas guidance.

No elevated concentrations of carbon dioxide or methane recorded from any of the monitoring undertaken and ground gas flow rates were recorded to be low on all occasions.

Based upon the available ground gas monitoring data, the risks from ground gas are likely to be low. However, the data limitations detailed above should be noted.

6.5 Uncertainties and Gaps in the Information

There has been limited asbestos testing undertaken from shallow soils, and no recent soil quality testing data is available for asbestos. Of particular concern with this regard is the area of Pingemead Industrial Estate. Elevated concentrations of metals, PAHs and TPH may arise from more recent activities at the Industrial Estate, and historical ground investigation findings may not be representative of current conditions.

There has been little soil testing for organic contaminants within the Phase 1C East and Phase 2 areas, in particular an absence of sufficient testing for TPH, VOCs and SVOCs. Despite this, within the area of Pingemead Industrial Estate, potential risks from TPH in soils and leachate have been identified. Due to the non-specific nature of the majority of the testing undertaken, comparison to GAC for soils may be over-conservative.

Further soil testing, particularly within the upper Made Ground at Pingemead Industrial Estate, is recommended, and should include speciated PAHs and TPH, metals, asbestos, bacteriological determinants and VOCs. This should include sampling from the area of current/former potential point sources of contamination such as chemical storage/use areas, tanks and cesspits, and within the footprint of existing industrial buildings.

The cause of apparent contamination at BH106 in groundwater of Made Ground / Alluvium is unclear as there is no known specific source of pollution in this part of the Phase 1C East. There are uncertainties surrounding the water quality at BH106. However, further actions are not recommended to address this because the potential contaminants identified relate to pollutants which are anticipated to be diffuse within shallow groundwater. The proposed development (road construction) in the area of Phase 1C East would not be anticipated to result in deterioration of water quality by creation of any pollutant linkage, although if the affected area is more widespread, piling of new buildings could introduce new pathways for migration of contaminants from shallow groundwater to groundwater at depth.

The level of gas monitoring undertaken to date is not sufficient to comply with current British Standards and UK specific guidance, and has been undertaken at a limited number of locations. Further monitoring is recommended.

6.6 Risk Evaluation and Conceptual Model

The elevated concentrations of substances in Made Ground would be unlikely to pose a risk to human health of end users given that ground levels are proposed to be raised by approximately 1.2 m or more. Made ground soils excavated from the area of the Pingemead Industrial Estate would not be suitable for reuse within residential gardens or areas of soft landscaping unless covered by a suitable clean soil and tested to ascertain that they will not pose a risk to controlled waters. Subject to leachate testing the soils may be suitable for use elsewhere on site. Control of the release of any substances from excavated Made Ground soils would be required, and would be mitigated by suitable site construction practices. Risks to construction workers could similarly be mitigated by suitable site construction practices in addition to use of standard construction Personal Protective Equipment (PPE).

Potential risks from TPH in soils and groundwater at Pingemead Industrial Estate to underlying aquifers and nearby surface water bodies (ditches and the Trout Lakes within the site) have been identified. These potential risks should be further considered in the context of detailed quantitative risk assessment in order to ascertain whether the potential risks are likely to be realised, and if required, to derive remedial targets.

The existing north-south trending ditch on site is not shown on plans of the proposed development. If this ditch is in-filled, the existing water within the ditch will require removal, appropriate disposal and alternative drainage will be needed. Particular care will be required to ascertain that fill material placed within the watercourse will not pose a risk of leaching of contaminants.

The qualitative hazard assessment identifying potential pollutant linkages has been undertaken below using the source-pathway-receptor framework detailed in Appendix 1. An assessment of the potential significance of each linkage has been made by consideration of the likely magnitude and mobility of the source, the sensitivity of the receptor and nature of the migration/exposure pathways.

Table 15 Phase 2 and Phase 1C Conceptual Site Model

Potential Source	Potential Contaminant (s)	Pathway	Potential Receptor	Probability of Risk Being Realised*	Consequence of Risk Being Realised*	Risk Classification*
Made Ground at Pingemead Industrial Estate (including bund on western boundary, within the Phase 1 West area)	Asbestos in soils	Inhalation of released fibres	Construction workers	Low likelihood	Severe	Moderate
			Adjacent site and phase users	Unlikely	Severe	Moderate/low
	Metals and PAHs in soils (in particular PAHs at TP209)	Dermal contact	Construction workers	Likely	Minor	Low
		Inhalation of soil dust	Construction workers	Likely	Mild	Moderate/low
			Adjacent site and phase users	Low likelihood	Mild	Low
		Ingestion of soil	Construction workers	Low likelihood	Mild	Low
			Construction workers	Low likelihood	Mild	Low
	TPH in soil Possible chlorinated solvents in soil	Dermal contact	Construction workers	Likely	Mild	Moderate/low
		Inhalation of soil dust	Construction workers	Likely	Mild	Moderate/low
			Adjacent site and phase users	Low likelihood	Mild	Low
		Ingestion of soil	Construction workers	Likely	Mild	Moderate/low
			Construction workers	Low likelihood	Mild	Low
		Inhalation of vapours	Adjacent site and phase users	Unlikely	Mild	Very low
			Future site users	Low likelihood	Medium	Moderate/low
			Future site users	Low likelihood	Medium	Moderate/low
	TPH in soil and/or groundwater (including potential free phase)	Leaching to groundwater and migration in groundwater	Secondary Aquifers (River Terrace Deposits and Lambeth Group)	Likely	Medium	Moderate
			Principal Aquifer (Chalk)	Low likelihood	Medium	Moderate/low
		Pollutant linkages created by piling	Surface water – Trout Lakes and ditches	Likely	Medium	Moderate

	TPH and potential chlorinated solvents in soil and/or groundwater (including potential free phase)	Permeation of buried water service pipes	Future site users	Unlikely (providing pipes are laid in clean cover material to be placed over the Made Ground)	Medium	Low
Shallow groundwater in Alluvium and River Terrace Deposits at Pingemead Industrial Estate	Chlorinated solvents in groundwater	Migration in groundwater, including vertical pathway creation via foundations from shallow to deeper aquifers	Secondary Aquifers (River Terrace Deposits and Lambeth Group)	Likely	Medium	Moderate
			Principal Aquifer (Chalk)	Low likelihood	Medium	Moderate/low
			Surface water – Trout Lakes and ditches	Low likelihood	Medium	Moderate/low
		Vapour inhalation	Construction workers	Low likelihood	Mild	Low
		Vapour inhalation	Future site users	Low likelihood	Medium	Moderate/low
Groundwater in the Made Ground at BH106	Nickel and chromium	Migration in groundwater	Secondary Aquifers (River Terrace Deposits and Lambeth Group)	Likely	Mild (not within a groundwater source protection zone)	Moderate/low
		Pathways created by piling	Principal Aquifer (Chalk)	Low likelihood	Mild (not within a groundwater source protection zone)	Low
Hydrocarbons, Made Ground, Alluvium and Chalk	Ground gases	Migration of gases and build up in confined spaces	Construction workers	Low likelihood	Medium	Moderate/low
			Future site users	Likely	Medium	Moderate
			Building structures	Likely	Medium	Moderate
		Lateral gas migration caused by development design	Adjacent site and phase users	Low likelihood	Medium	Moderate/low
			Adjacent building structures	Low likelihood	Medium	Moderate/low
Cess pits	Bacteria/pathogens	Dermal contact	Construction workers	Unlikely	Mild	Very low
	Ammonia	Inhalation of soil dust	Construction workers	Unlikely	Mild	Very low
	Phosphate and nitrates		Adjacent site and phase users	Unlikely	Mild	Very low
	Heavy metals	Ingestion of soil	Construction workers	Low likelihood	Mild	Low

		Leaching to groundwater and migration in groundwater	Secondary Aquifers (River Terrace Deposits and Lambeth Group)	Low likelihood	Mild	Low
			Principal Aquifer (Chalk)	Unlikely	Mild	Very low
			Surface water – Trout Lakes and ditches	Low likelihood	Medium	Moderate/low
Diffuse, regional groundwater contamination	Ammonia and manganese	Vertical and lateral migration via permeable strata	Secondary Aquifers (River Terrace Deposits and Lambeth Group)	Low likelihood	Mild	Low
			Principal Aquifer (Chalk)	Low likelihood	Mild	Low

Note All risks assume no mitigation in place - for definition of terms see Appendix 1 (Assessment Criteria) * Based upon PBA 2015 assessment of gas monitoring data only

6.7 Conclusions

It is necessary to raise ground levels by over a metre across the whole of the Phase 2 and Phase 1C East. Phase 2B East has been used for the storage of soil stockpiles. Phase 2B West is currently occupied by a derelict industrial estate, the mid-northern part of Phase 1C has been utilised for a yard serving the industrial estate, and Phase 2A has been utilised for residential purposes. The majority of the remainder of the site has been vacant land.

A number of potential pollutant linkages are present at the remainder of the Phase 1C East and Phase 2, which will require further investigation and risk assessment to determine whether any remedial measures are required. These include the following risks:

- i. Asbestos in Made Ground, for which there has been little testing;
- ii. Bacteria/pathogens within soil or groundwater near to cess pits at Pingemead Industrial Estate;
- iii. Hydrocarbons in soil and/or groundwater which may leach and affect water bodies;
- iv. Chlorinated solvents in groundwater of the Secondary Aquifers; and
- v. Ground gases which may build up in confined spaces causing a risk to end users and future building structures.

6.8 Recommendations and Implications for Design, Construction and Project Planning

Further ground investigation to ascertain the quality of groundwater and soil (heavy metals, hydrocarbons, chlorinated solvents and asbestos in particular), and the ground gas regime, is required within the area of Phase 1C East, Phase 2A, Phase 2B East and Phase 2C. In particular, additional investigation is required within the area of the Pingemead Industrial Estate. Additional gas monitoring should include for vapours, and it may be prudent to sample and test ground gas to determine its constituents.

Given that site levels are proposed to be raised, gas monitoring would be required to continue following placement of material to raise ground levels. This is necessary to ascertain whether lateral gas migration has been initiated as a result of the development scheme.

Pending the results of additional investigations, allowance should be made for the provision of ground gas protection measures to all buildings within Phases 2A, 2B West and 2C.

In the absence of specific testing beneath potential point sources of contamination and beneath industrial buildings, the further investigation is required to give particular attention to these areas. Allowance ought to be made for localised removal of hotspots of soils impacted by contamination. Detailed quantitative risk assessment is likely to be required to assess risks to controlled waters, and localised remediation may be necessary. Depending upon the proposed foundation solution, a piling risk / ground improvement assessment may be required if the solution could introduce pathways for contaminant migration.

Depending upon the findings of supplementary investigations, specific controls for the release of soil dust / asbestos fibres during site works may be required in order to protect ground workers and users of nearby land.

7. ASSESSMENT OF PHASE 3

7.1 Site Setting

Phase 3 is located in the eastern portion of the site, and is bounded by historic landfill sites to the north, a ditch at the southernmost boundary, and Phases 1 and 4 to the west and north respectively. Phase 3 occupies an area approximately 4.50 ha at a NGR of 470153, 170282. See Figure 2 for the site phasing plan.

Early Ordnance Survey mapping (1883) indicates that Phase 3 was undeveloped open land known as "Smallmead Common". By 2008 a training centre belonging to Thames Valley University and subsequently used as a maintenance and security depot were noted within the centre of Phase 3. Whilst Phase 3 is undeveloped open ground there was noted during a site visit by Ramboll consultants evidence of re-profiling of the ground and soil stockpiling. These stockpiles have been utilised for the purpose of land raising at Phase 1..

Information from the various historic ground investigations within Phase 3 indicates that the typical ground conditions comprise Topsoil, Made Ground (approximately 0.3 m to 1.47 m thick), underlain by Alluvium (approximately 0.1 m to 1.15 m thick); River Terrace Deposits (approximately 0.1 m to 2.75 m thick), overlying the Lambeth Group (approximately 0.3 m to 15.3 m thick), which is turn is underlain by the Chalk (depth unproven).

7.1.1. Soil Stockpiles

Assessment of the soil stockpiles within Phase 3 was made by PBA in 2015 (Green Park Village – Report on Ground Investigation for Phase 1A ref 30158 rev0). It is understood that the vast majority of the soil stockpiles originated from the Topsoil removal undertaken from other phases within the site, with some subsoil materials originating from service trenches, foundations etcetera.

PBA concluded that on the basis of the soil analysis undertaken up to May 2015 the soil stockpiles were not adversely impacted by any ground contamination. Therefore this material was considered by PBA as suitable for re-use without any remedial treatment and would not pose a hazard to the future site users. It is understood that this assessment has been agreed by the Local Planning Authority.

The soil stockpiles present within Phase 3 were placed within Phase 1 during the end of 2015 and start of 2016 to raise ground levels. During placement, material within the stockpiles was subject to sorting in accordance with the Specification for Earthworks. This sorting included the removal of potentially degradable material such as wood and chalk. Plaster board, metals and plastics were also stipulated within the Specification for Earthworks as being unsuitable for use within placed fill materials.

7.2 Proposals for the Phase 3

Phase 3 will comprise residential housing with gardens, areas of soft landscaping and associated infrastructure. The majority of the Phase 3 will need to be raised by approximately 2 m from the original ground level of 38 mAOD. This platform will effectively act as a cap to the underlying ground. The plans of the proposed development are shown in Drawing PL-MPL-005.

7.3 Summary of Exploratory Locations in Phase 3

Table 16 below provides a summary of exploratory holes advanced within Phase 3, including details of monitoring well installations, groundwater strikes and visual/olfactory evidence of contamination. A 5 m buffer zone has been applied to Phase 3 to capture all the relevant data adjacent the phase.

Table 16 Summary of Exploratory Locations in Phase 3

ID	Depth to Base of Hole (m bgl)	Groundwater Strike (m bgl)	Response Zone (m bgl)	Response Zone Strata	Visual/Olfactory Evidence of Contamination
BH104	18.3	0.2 and 6.7	12.00 - 17.00	Lambeth Group	None
BHG6	5	0.75	1.00 - 5.00	River Terrace Deposits and Lambeth Group	None
BHG7	5	0.8	1.00 - 5.00	River Terrace Deposits and Lambeth Group	Occasional brick and flint fragments with organic materials (plant debris and roots)

ID	Depth to Base of Hole (m bgl)	Groundwater Strike (m bgl)	Response Zone (m bgl)	Response Zone Strata	Visual/Olfactory Evidence of Contamination
BHG8	5	1.55	1.00 - 5.00	Made Ground and Alluvium and River Terrace Deposits and Lambeth Group	Occasional plant debris and ceramic fragment (0.55 m bgl)
TP203	1.85	0.9	-	-	None
TP205	1.9	0.75	-	-	None
TP206	3.1	2	-	-	Fragments of glass, plastic, wood, brick and metal
TP207	2.15	1.45	-	-	None
TP219	3	2.7	-	-	Fragments of flint gravel, brick and occasional pieces of timber
TP220	3	2.8	-	-	Fragments of brick, flints, timber, metal pipe and plastic fencing
TP221	2.5	2	-	-	Fragments of flint gravel, brick and occasional pieces of timber
G15	2	1.8	0.50 - 2.00	Made Ground and Alluvium	Large fragments of brick, concrete, pieces of string and black sandy clay
G16	3	2.5	0.50 - 3.00	Made Ground and Alluvium and River Terrace Deposits	Occasional fragments of brick and Chalk
G17	2	1.7	0.50 - 2.00	Made Ground and Alluvium and River Terrace Deposits	Occasional fragments of brick, stone, and tar. With organic material (roots) and black clay
G9	4.5	1.1	0.50 - 4.00	Made Ground and Alluvium and River Terrace Deposits	Black friable clay, brick, glass and plant rootlets
G10	4.5	0.7	0.50 - 4.00	Made Ground and Alluvium and River Terrace Deposits and Lambeth Group	Black friable clay, brick and green glass
G11	4.5	0.7	0.50 - 4.00	Alluvium and River Terrace Deposits and Lambeth Group	None
TP107	0.8	0.8	-	-	None
TP111	2.5	2.4	-	-	Stockpile; flint gravel and organic material

ID	Depth to Base of Hole (m bgl)	Groundwater Strike (m bgl)	Response Zone (m bgl)	Response Zone Strata	Visual/Olfactory Evidence of Contamination
TP115	1.6	1.3	-	-	Stockpile; fragments of brick, concrete (kerbside), metal rods/rebar, timber planks, geotextile and cloth
TP116	3.8	1.7	-	-	Stockpile; fragments of brick, concrete, metal, geotextile, cloth and organic materials (roots)
WS02_2015	4	0.4	0.10 - 3.00	Made Ground and Alluvium and River Terrace Deposits	Brick, concrete and flint
WS04_2015	2.5	0.3	0.10 - 2.00	Topsoil and Alluvium and River Terrace Deposits and Lambeth Group	None
Contained within the 5 m buffer zone					
BH105	25	0.65	20.00 – 25.00	Chalk	None
WS03_2015	2.5	0.5	0.10 – 0.80	River Terrace Deposits	None

7.4 Evaluation and Assessment of Results

The evaluation and assessment of the results from Phase 3 were based upon the findings of the following previous investigations:

- Peter Brett Associates, Geo-environmental Investigation for Phase III, Green Park, Reading, (August 2002) exploratory hole locations BH104, BH105, BHG6, BHG7, BHG8, TP203, TP205, TP206 and TP207;
- Peter Brett Associates, Earthwork Material Suitability Assessment. Phase III, Green Park, Reading, (November 2005) exploratory hole locations TP219, TP220, TP221, G15, G16 and G17;
- Peter Brett Associates, Gas and Water Quality Monitoring Report, Green Park Village, (July 2007) exploratory hole locations G9, G10 and G11; and
- Peter Brett Associates, Report on Ground Investigation for Phase 1A. Green Park Village, (May 2015) exploratory hole locations TP107, TP111, TP115, TP116, WS02_2015, WS03_2015 and WS04_2015.

7.4.1. Soil Results – Human Health Risk Assessment

Comparison of soil results has been made to the GAC for a residential with plant uptake end use, as a preliminary worst case scenario. This conservative approach assumes that soft landscaping will be present throughout Phase 3.

Testing for a range of metals and metalloids, TPH and PAHs was routinely undertaken within Phase 3 area from Made Ground, the natural strata and soil stockpiles.

Metals and Metalloids

Lead

An elevated lead concentration (227 mg/kg) was encountered in TP207 within the Topsoil and Alluvium, at a depth of 0.30 m bgl. The exceedance recorded was marginally higher than the GAC (200 mg/kg). Due to the marginal, isolated occurrence and the proposed land raise, this exceedance is not considered to pose a significant risk to end users (see Figure 15).

Mercury

An elevated mercury concentration (3 mg/kg) was encountered in excess of the GAC at TP207 within the Topsoil and Alluvium at a depth of 0.30 m bgl. The exceedance of mercury was made with reference to elemental mercury which is considered a conservative approach.

When compared against the GAC for inorganic mercury, no exceedance was recorded. Given the low likelihood that the mercury concentration relates entirely to elemental mercury, it is unlikely that the recorded mercury concentration represents a risk to end users at the site (see Figure 14).

Other Metals and Metalloids

Concentrations of all other metals and metalloids (e.g. arsenic, cadmium, copper, nickel, selenium and zinc) were all recorded at concentrations below residential GAC.

Total Petroleum Hydrocarbons (TPH)

TPH was tested for in soils routinely across the Phase 3 area. The majority of the testing undertaken was for total TPH, without speciation by carbon chain length or by aliphatic/aromatic type. In some instances, the TPH tested for comprised only extractable petroleum hydrocarbons (EPH) taken as carbon chain lengths C10-40.

The recorded TPH concentrations were therefore based on the most conservative of the relevant fractions listed within the GAC. No BTEX or MTBE compounds were identified within Phase 3. The TPH results which show concentrations to be above the relevant GAC are shown in Table 17 and Figure 19.

Table 17 Potentially Elevated Concentrations of TPHs

ID	Description	Depth of Sample (m bgl)	Concentration (mg/kg)	Strata
TP203	Mineral oil/paraffin	0.40	44	Topsoil and Alluvium
TP206	Mineral oil/paraffin	0.40	109	Made Ground
TP207	Mineral oil/paraffin	0.30	360	Topsoil and Alluvium
TP219	EPH	0.50	151	Made Ground
TP220	EPH	1.00	207	Made Ground

Results for TPH suggest a potential risk via permeation of buried water supply pipes, and it is anticipated that the water supply company may consider the use of polyethylene pipes to be inappropriate in Phase 3, unless installed within the clean cap material.

Polycyclic Aromatic Hydrocarbons (PAHs)

Elevated concentrations of PAHs were encountered at shallow depths (0.30 m bgl to 0.40 m bgl) within TP203, TP206 and TP207. Adopting a conservative approach, comparison of concentrations of total PAH were applied to the GAC for benzo(a)pyrene, a surrogate marker (for which the GAC is 5 mg/kg). Table 18 displays the elevated concentrations of PAH within Phase 3 (see Figure 17).

Table 18 Elevated Concentrations of PAHs

ID	Depth of Sample (m bgl)	Concentration (mg/kg)	Strata
TP203	0.40	44	Topsoil and Alluvium
TP206	0.40	18	Made Ground
TP207	0.30	45	Topsoil and Alluvium

7.4.2. Summary TPHs and PAHs Results

The majority of the Phase 3 area will need to be raised by approximately 2 m from the original ground level of 38 mAOD. This platform will effectively act as a cap to the underlying ground.

Therefore elevated concentrations of TPH and PAH are not considered to pose a significant risk to end users. There is the potential risk of ingress of hydrocarbons or other organics into water supply pipes by permeation of plastic pipe materials. The Made Ground from the Phase 3 would not however be likely to be suitable for reuse elsewhere within the GPV site unless deemed appropriate by specific testing and placed beneath buildings, hard surfacing, or an adequate thickness (at least 600 mm) of clean cover material.

Asbestos

During the historic ground investigations no visual evidence of asbestos was recorded within Phase 3. It is noted that minimal analysis of asbestos in soils was undertaken within the Phase (see Figure 12).

7.4.3. Soil Results – Groundwater Risk Assessment

Soil Leachate

No soil samples were scheduled for leachate analysis during the historic ground investigations within Phase 3. No free phase hydrocarbons were identified from the investigations.

Groundwater Results

Adopting a conservative approach, comparison of concentrations of determinands in groundwater has been made to Environmental Quality Standards (EQS) for freshwater and, where these are not available, to UK Drinking Water Standards (DWS).

Metals and Metalloids

Chromium

Elevated concentrations of chromium were encountered within BHG8 (15 µg/l), BH104 (13 µg/l) and BH105 (4 µg/l and 12 µg/l). The elevated concentrations were recorded in several strata including within standpipes installed across the Made Ground, River Terrace Deposits, Lambeth Group and the Chalk). Adopting a conservative approach, comparison of concentrations of chromium was made to the GAC for chromium VI (3.4 µg/l). Should the 95th percentile GAC (32 µg/l) for total chromium be adopted no exceedances would be recorded. Statistical tests are used to calculate the 95% probability that the true population mean falls below the critical concentration (GAC). In practise, this involves comparing the 95th Upper Confidence Limit of the true population mean with the GAC. The risk to controlled waters is considered to be low and will not be evaluated further as part of this assessment (see Figure 22).

Copper

Elevated concentrations of copper were encountered within BHG6 (32 µg/l) and BH105 (38 µg/l) on two occasions when groundwater monitoring was undertaken. Comparison of concentrations of copper were applied to the GAC (10 µg/l) (see Figure 23).

The elevated concentrations of copper occurred in both the natural strata (River Terrace Deposits and Lambeth Group and the Chalk). Considering the isolated and marginal nature of these exceedances, it is unlikely that the recorded copper concentrations represent a risk to controlled waters or human health.

Manganese

Groundwater samples were analysed for manganese in two ground investigations dating back to 2002 and 2007. Elevated concentrations of manganese were encountered within BHG8 (which range from 48 µg/l to 123 µg/l), BH104 (100 µg/l to 241 µg/l), BH105 (90 µg/l to 219 µg/l) and BH106 (271 µg/l). Comparisons of concentrations of manganese were applied to the GAC (30 µg/l) (see Figure 26).

The elevated concentrations of manganese occurred in both the natural strata (River Terrace Deposits, Lambeth Group and the Chalk) and within the Made Ground. Manganese within the groundwater is likely to reflect natural background levels and this has been ascertained by a review of some nearby EA monitoring well data (PBA, 2009).

Nickel

An elevated concentration of nickel was encountered on one occasion within BHG8 (26 µg/l). The exceedance recorded was marginally above the GAC (20 µg/l). The elevated concentration of nickel occurred within the River Terrace Deposits and the Made Ground. The slight exceedance of the GAC and its isolated occurrence represents a low level of risk to controlled waters (see Figure 28).

Selenium

An elevated concentration of selenium was encountered on one occasion within BH104 (11 µg/l). The exceedance recorded was marginally above the GAC (10 µg/l). The elevated concentration of selenium occurred within the natural strata of the Lambeth Group. The slight exceedance of the GAC and its isolated occurrence represents a low level of risk to controlled waters or human health (see Figure 30).

Ammonia

Elevated concentrations of ammonia were encountered within BHG6 (600 µg/l), BH104 (300 µg/l to 700 µg/l) and BH105 (900 µg/l and 1600 µg/l). Adopting a conservative approach, comparison of concentrations of ammonia was applied to the GAC of 300 µg/l. The elevated concentrations of ammonia occurred within the shallower groundwater for instance the River Terrace Deposits, although ammonia was also identified in the Lambeth Group and the Chalk (see Figure 20).

A high concentration of ammonia indicates that elevated concentrations of nitrates from fertilisers, for example, may be present. This is likely to be diffuse. Discussions with the EA should be held to highlight the diffuse nature of this contamination and why site specific remediation would be unlikely to be of benefit.

Nitrate

Elevated concentrations of nitrate were encountered within BHG6 (3200 µg/l), BH104 (400 µg/l) and BH105 (900 µg/l). The elevated concentrations of nitrate occurred within the shallower groundwater for instance the River Terrace Deposits, although nitrate was also identified in the Lambeth Group and the Chalk (see Figure 29).

5.4.5 Total Petroleum Hydrocarbons (TPH)

The GAC used to assess TPH concentrations was the UK Drinking Water Standard (10 µg/l), which is a highly conservative approach. Elevated concentrations of TPH were recorded in 2002 at BH105 in groundwater within the Chalk. There is no known specific source for TPH in groundwater in the Chalk at this location. The recorded concentration of 2000 µg/l was identified using infra-red (IR) methods. IR methods are prone to interferences from non-petroleum sources, and the TPH identified could relate

to other organic substances. This result should therefore be treated with caution as it is not likely to represent an existent risk (see Figure 33).

Phenols

No elevated concentrations of phenols in excess of the GAC were identified in groundwater in Phase 3 (see Figure 34).

7.4.4. Surface Water Results

Surface water samples collected from Ditch 8, located on the eastern boundary of Phase 3 recorded 0.11 µg/l of PAH, on one occasion in 2005. Due to the isolated occurrence, the exceedance is not considered to pose a significant risk to controlled waters or human health (see Figure 38).

Ground Gas

Potential sources of ground gas in the Phase 3 area include:

- i. Natural sources such as the decay of organic material in Alluvium, typically around 0.1 to 1.15 m thick;
- ii. Natural sources such as the dissolution of Chalk;
- iii. Decay of anthropogenic material and plant material (e.g. roots) in Made Ground which has been identified at thicknesses of up to 1.47 m; and
- iv. The historic landfills immediately adjacent to the north of Phase 3.

Ground gas monitoring was undertaken by PBA at nine locations: G9 (five visits), G10 (five visits), G11 (five visits), G15 (four visits), G16 (four visits), G17 (four visits), WS02_2015 (six visits), WS03_2015 (six visits) and WS04_2015 (six visits). BH104 was discounted due to the well being flooded. Monitoring was undertaken at atmospheric pressure conditions ranging from 976 mb to 1009 mb. Table 19 shows the peak ground gas results for Phase 3 and the ground gas plan is illustrated in Figure 40.

Table 19 Phase 3 –Peak Ground Gas Results

ID	Response Zone (m bgl)	Water Level (m bgl)	Peak Carbon Dioxide (CO ₂) Concentration (% v/v)	Peak Methane (CH ₄) Concentration (% v/v)	Gas Flow Rate (l/hr)
G15	0.50 - 2.00	2.05	1.3	0.0	0.3
G16	0.50 - 3.00	1.75	0.2	0.0	0.0
G17	0.50 - 2.00	1.53	1.4	0.0	0.0
G9	0.50 - 4.00	2.89	0.3	0.0	0.0
G10	0.50 - 4.00	1.0	1.9	0.0	0.0
G11	0.50 - 4.00	3.48	3.3	0.0	0.0
WS02_2015	0.10 - 3.00	2.80	2	0.0	0.6
WS04_2015	0.10 - 2.00	1.34	1.2	0.0	0.2
WS03_2015	0.10 - 0.80	0.66	2	0.0	0.0

Carbon dioxide concentrations were all <5% v/v and methane concentrations were all recorded to be <1% v/v. Flow rates were consistently recorded below the detection limit of <0.1 l/hr, with the exception of those taken from G15 (0.3 l/hr), WS02_2015 (0.6 l/hr) and WS04_2015 (0.2 l/hr). A worst case scenario was adopted to calculate the potential risks posed by ground gases at Phase 3.

The overall gas screening value (GSV) for methane has been calculated to be 0.00 l/hr and for carbon dioxide 0.02 l/hr. From the limited ground gas information available for Phase 3, the data indicates an overall classification of 'Characteristic Situation 1'. Risks from ground gas are therefore considered to be a low but further monitoring is recommended.

7.5 Uncertainties and Gaps in the Information

Although no significant gas risk has been identified from the monitoring undertaken to date, additional rounds of ground gas monitoring are required within Phase 3 to comply with current UK guidance for a development which includes residential land use. This must be done from wells which are appropriately designed (e.g. well screen above the water table and in the response zone which is appropriate to monitor). Better quality and more recent data will enable a more efficient design of any potential gas remedial measures. Subsequently, should Phase 3 require remedial measures these will need to be designed in accordance with current best practice.

Previous soil testing was not always carried out for fully speciated organic compounds (PAHs and TPHs) which renders assessment to current standards difficult. Consequently the methodology adopted as part with this assessment is likely to be overly conservative as the worst case conditions have been considered.

The typical exploratory hole spacing within Phase 3 is considered to be unsuitable for ground gas monitoring, for instance gaps along the southern perimeter and eastern portions of Phase 3. Furthermore there is no record of investigations being undertaken to date which have assessed the risks of the onsite maintenance and security depot located within the centre of Phase 3.

Insufficient data has been obtained relating to groundwater. In addition, where soil concentrations were found to be high, no leachate analysis was undertaken in order to assess the likelihood of the impacted soils affecting water quality. During the historic ground investigations no visual evidence of asbestos was recorded within Phase 3 however this does not preclude its presence and no soils or Made Ground were screened for asbestos.

Further investigation is required to assess risks posed from the migration of contaminants to Phase 3 from offsite sources, including the historic landfill sites surrounding Phase 3 to the north.

7.6 Risk Evaluation and Conceptual Model

Ramboll has reviewed the historic ground investigation data and in the preceding sections to identify the potential contamination sources, pathways and receptors that are present within Phase 3 in relation to the proposed development. This assessment has been undertaken in order to define the conceptual site model for Phase 3 that is presented Table 20.

The elevated lead, mercury, TPH and PAH concentrations recorded in Phase 3 would be unlikely to pose a risk to human health of future site users given that ground levels are proposed to be raised by approximately 2 m in the affected areas. There is the potential risk of ingress of hydrocarbons or other organics into the water supply pipes by permeation of plastic pipe materials, subsequently potentially affecting future site users.

Made Ground soils excavated from Phase 3 would not however be suitable for reuse within residential gardens or areas of soft landscaping unless covered by a suitable clean soil capping and will be subject to leachate testing. Control of the release of any substances from excavated Made Ground soils would be required and could be mitigated by suitable site construction practices. Risks to construction workers could similarly be mitigated by suitable site construction practices in addition to use of standard construction Personal Protective Equipment (PPE).

The elevated metals, ammonia and nitrate concentrations in groundwater recorded in Phase 3 would be unlikely to pose a risk to controlled waters. Potential risks from TPH in groundwater in Chalk have been identified. The potential risk should be further considered in the context of detailed quantitative risk assessment in order to ascertain whether the potential risk is likely to be realised, and if required, to derive remedial targets, such as leachate analysis and gas monitoring.

The qualitative hazard assessment identifying potential pollutant linkages has been undertaken below using the source-pathway-receptor framework detailed in Appendix 1. An assessment of the potential significance of each linkage has been made by consideration of the likely magnitude and mobility of the source, the sensitivity of the receptor and nature of the migration/exposure pathways.

Table 20 Phase 3 Conceptual Site Model

Potential Source	Potential Contaminant (s)	Pathway	Potential Receptor	Probability of Risk Being Realised*	Consequence of Risk Being Realised*	Risk Classification*
Made Ground and (on site)	Asbestos in soils	Inhalation of released fibres	Construction workers	Low likelihood	Severe	Moderate risk
			Adjacent site and phase users	Unlikely	Severe	Moderate/low risk
	Metal and metalloids in soils	Dermal contact	Construction workers	Likely	Minor	Low risk
		Inhalation of soil dust	Construction workers	Likely	Mild	Moderate/low risk
			Adjacent site and phase users	Low likelihood	Mild	Low risk
		Ingestion of soil	Construction workers	Low likelihood	Mild	Low risk
		Leaching to groundwater and migration in groundwater	Secondary Aquifers (River Terrace Deposits and Lambeth Group)	Likely likelihood	Mild (not within a groundwater source protection zone)	Moderate / Low risk
			Principal Aquifer (Chalk)	Low likelihood	Mild (not within a groundwater source protection zone)	Low risk
			Surface water – ditches	Low likelihood	Mild	Low risk
	TPH and PAH in soil	Dermal contact	Construction workers	Likely	Mild	Moderate/low risk
		Inhalation of soil dust	Construction workers	Likely	Mild	Moderate/low risk
			Adjacent site and phase users	Low likelihood	Mild	Low risk
		Ingestion of soil	Construction workers	Likely	Mild	Moderate/low risk
		Inhalation of vapours	Construction workers	Low likelihood	Mild	Low risk
			Adjacent site and phase users	Unlikely	Mild	Very low risk
			Future site users	Low likelihood	Medium	Moderate/low risk
		Leaching to groundwater and migration in groundwater	Secondary Aquifers (River Terrace Deposits and Lambeth Group)	Likely	Mild (not within a groundwater source protection zone)	Moderate / Low risk

			Principal Aquifer (Chalk)	Low likelihood	Mild (not within a groundwater source protection zone)	Low risk
			Surface water – ditches	Low likelihood	Mild	Low risk
		Permeation of buried water supply pipes	Future site users	Unlikely	Medium	Low risk
Made Ground, Alluvium and Chalk	Ground gases	Migration of gases and build up in confined spaces	Construction workers	Unlikely	Medium	Low risk
			Future site users	Low likelihood	Medium	Moderate/low risk
			Building structures	Low likelihood	Medium	Moderate/low risk
		Lateral gas migration caused by development design	Adjacent site and phase users	Unlikely	Medium	Low
			Adjacent building structures	Unlikely	Medium	Low
Groundwater in the Chalk at BH105	Copper, chromium and TPH	Migration in groundwater	Principal Aquifer (Chalk)	Likely	Mild (not within a groundwater source protection zone)	Moderate/low risk
Maintenance and security depot (onsite)	TPH, PAH, fuels, hydraulic oils, lubricating oils and metals	Dermal contact	Construction workers	Likely	Mild	Moderate/low risk
		Inhalation of soil dust	Construction workers	Likely	Mild	Moderate/low risk
			Adjacent site and phase users	Low likelihood	Mild	Low risk
		Inhalation of vapours	Construction workers	Low likelihood	Mild	Low risk
			Adjacent site and phase users	Unlikely	Mild	Very low risk
			Future site users	Low likelihood	Mild	Low risk
		Migration in groundwater	Secondary Aquifers (River Terrace Deposits and Lambeth Group)	Likely	Mild (not within a groundwater source protection zone)	Moderate/low risk
			Principal Aquifer (Chalk)	Low likelihood	Mild (not within a groundwater source protection zone)	Low Risk
		Surface water	Surface water – ditches	Low likelihood	Mild	Low risk

		Permeation of buried water supply pipes	Future site users	Unlikely	Medium	Low risk
Offsite historic landfills	Landfill leachate	Downward and subsequently lateral migration of landfill leachate into underlying aquifer	Secondary Aquifers (River Terrace Deposits and Lambeth Group)	Low likelihood	Mild	Low risk
			Principal Aquifer (Chalk)	Unlikely	Mild	Very low risk
		Surface water	Surface water – ditches	Unlikely	Medium	Low risk
	Ground gas	Gases may migrate into confined spaces such as buildings	Construction workers	Unlikely	Medium	Low risk
			Future site users	Low likelihood	Medium	Moderate/low risk
			Building structures	Low likelihood	Medium	Moderate/low risk
Diffuse, regional groundwater contamination	Ammonia and manganese	Vertical and lateral migration via permeable strata	Surface water – ditches	Low likelihood	Mild	Low risk
			Secondary Aquifers (River Terrace Deposits and Lambeth Group)	Low likelihood	Mild (not within a groundwater source protection zone)	Low risk
			Principal Aquifer (Chalk)	Low likelihood	Mild (not within a groundwater source protection zone)	Low risk

Note All risks assume no mitigation in place - for definition of terms see Appendix 1

7.7 Conclusions

Phase 3 is currently open ground and had been utilised to stockpile soil materials for raising site levels within Phase 1. The majority of the Phase 3 will need to be raised by around 2 m from the original ground level of 38 mAOD. This platform will effectively act as a cap to the underlying ground. The proposed development of Phase 3 will comprise residential housing with gardens and areas of soft landscaping.

Ramboll have reviewed the previous ground investigation reports undertaken by PBA to identify potential pollutant linkages, and has carried out a risk assessment in line with current published guidance, to determine whether any remedial measures are required. These include the following risks:

- i. Potential for asbestos in Made Ground, as no testing was undertaken;
- ii. TPH within the groundwater has been identified;
- iii. The Made Ground soils excavated from Phase 3 would not be suitable for reuse within residential gardens or areas of soft landscaping unless covered by a suitable clean soil; and
- iv. No significant gas risk has been identified from the monitoring undertaken to date, however additional rounds of ground gas monitoring are required to comply with current UK guidance.

7.8 Recommendations and Implications for Design, Construction and Project Planning

Further ground investigation to ascertain the quality of groundwater and soil (hydrocarbons and asbestos, in particular) is required within Phase 3 and specifically within the former maintenance depot.

Although no significant ground gas risk (CS1) has been identified, additional ground gas monitoring is required to comply with current UK guidance. The ground gas monitoring should include for vapours, and it may be prudent to sample and test ground gas to determine its constituents (such as potential sources from landfill). Given that site levels are proposed to be raised, ground gas monitoring would be required to continue following placement of material to raise ground levels. This is necessary to ascertain whether lateral gas migration has been introduced as a result of the development scheme.

In the absence of specific testing beneath potential areas of contamination, such as the maintenance and security depot, further investigation is required within this area. An allowance ought to be made for localised removal of hotspots of soils impacted by contamination in this area.

Depending upon the proposed foundation solution, a piling risk / ground improvement assessment may be required if the solution could introduce pathways for contaminant migration into aquifers beneath the site.

Depending upon the findings of supplementary ground investigations, specific controls for the release of soil dust / asbestos fibres during site works may be required in order to protect ground workers and users of nearby land. Any soils imported to Phase 3 will require chemical testing to ascertain suitability for use prior to being placed.

8. ASSESSMENT OF PHASE 4

8.1 Site Setting

Phase 4 is located in the north eastern portion of the site, and is bounded by historic landfill sites and a ditch to the north. Phases 1, 3 and 5 are located to the south, east and west of Phase 4 respectively. Phase 4 occupies an area approximately 2.50 ha at a NGR 470018, 170349. See Figure 2 for the site phasing plan.

Early Ordnance Survey mapping (1883) indicates that Phase 4 was undeveloped open land known as "Smallmead Common". Whilst Phase 4 is undeveloped open ground there was noted during a site visit

by Ramboll consultants evidence of re-profiling of the ground and stockpiling. These stockpiles have been utilised for the purpose of land raising at Phase 1.

Information from the various historic ground investigations in Phase 4 indicates that the typical ground conditions comprise Topsoil, Made Ground (approximately 0.8 m to 1.80 m thick), underlain by Alluvium (approximately 0.2 m to 1.5 m thick); River Terrace Deposits (approximately 0.2 m to 3.2 m thick), overlying the Lambeth Group (approximately 1.1 m to 7.3 m thick), which is turn is underlain by the Chalk (depth unproven).

8.1.1 Soil Stockpiles

Assessment of the soil stockpiles within Phase 4 was made by PBA in 2015 (Green Park Village – Report on Ground Investigation for Phase 1A ref 30158 rev0). It is understood that the vast majority of the soil stockpiles originated from the Topsoil removal undertaken from other plots within the site, along with some subsoil materials originating from service trenches, foundations etc.

PBA concluded that on the basis of the soil analysis undertaken up to May 2015 the soil stockpiles were not adversely impacted by any ground contamination. Therefore this material was considered by PBA as suitable for re-use without any remedial treatment and would not pose a hazard to the future site users. It is understood that this assessment has been agreed by the Local Planning Authority.

The soil stockpiles present within Phase 4 were placed within Phase 1 during the end of 2015 and start of 2016 to raise ground levels. During placement, material within the stockpiles was subject to sorting in accordance with the Specification for Earthworks. This sorting included the removal of potentially degradable material such as wood and chalk. Plaster board, metals and plastics were also stipulated within the Specification for Earthworks as being unsuitable for use within placed fill materials.

8.2 Proposals for the Phase 4

Phase 4 will comprise residential housing with gardens, areas of soft landscaping and associated infrastructure. The majority of the Phase 4 will need to be raised by approximately 2 m from the original ground level of 38 mAOD. This platform will effectively act as a cap to the underlying ground. The plans of the proposed development are shown in Drawing PL-MPL-005.

8.3 Summary of Exploratory Locations in Phase 4

Table 21 below provides a summary of exploratory holes advanced within Phase 4, including details of monitoring well installations, groundwater strikes and visual/olfactory evidence of contamination. A 5 m buffer zone has been applied to Phase 4 to capture all the relevant data adjacent the phase.

Table 21 Summary of Exploratory Locations in Phase 4

ID	Depth to Base of Hole (m bgl)	Groundwater Strike (m bgl)	Response Zone (m bgl)	Response Zone Strata	Visual/olfactory Evidence of Contamination
BH103	10	1.1 and 7.5	1.00 - 2.70	Alluvium and River Terrace Deposits	None
BHG4	3	1.2	1.20 - 5.00	River Terrace Deposits and Lambeth Group	None
BHG5	5	1.2	1.00 - 5.00	Alluvium and River Terrace Deposits and Lambeth Group	None
TP204	2.8	1.7	-	-	None
TP222	3	2.3	-	-	Occasional brick, flint gravel and masonry (some lumps of red brown clay)

ID	Depth to Base of Hole (m bgl)	Groundwater Strike (m bgl)	Response Zone (m bgl)	Response Zone Strata	Visual/olfactory Evidence of Contamination
TP223	3	2.1	-	-	Occasional brick, flint, timber, plastic (plastic tile) and fragments of china
G18	2	No record	0.50 - 2.00	Made Ground and Alluvium and River Terrace Deposits	Occasional brick, flint, concrete and fragments of glass
G12	4.5	0.8	0.50 - 4.00	Alluvium and River Terrace Deposits and Lambeth Group	None
G13	4.5	0.8	0.50 - 4.00	Alluvium and River Terrace Deposits and Lambeth Group	None
G14	4.5	0.9	1.00 - 4.45	Alluvium and River Terrace Deposits and Lambeth Group	None
TP110	2.3	2.3	-	-	Stockpile; tarmac, concrete, flint gravel and organic material
TP117	2.7	2.7	-	-	Stockpile; occasional bricks, concrete, kerbstone, plastic and timber fragments
TP118	2.7	2.6	-	-	Concrete (kerbstone), brick, metal, timber planks, geotextile, rubber and organic material
TP119	1.3	Dry	-	-	Stockpile; occasional brick, sawn timber, plastic and roots
WS03_2015	2.5	0.5	0.10 - 0.80	Topsoil and River Terrace Deposits	None
Contained within the 5 m buffer zone					
G16	3	2.5	0.50 - 3.00	Made Ground and Alluvium and River Terrace Deposits	Occasional fragments of brick and Chalk
TP103	2.4	No record	-	-	None

8.4 Evaluation and Assessment of Results

The evaluation and assessment of the results from Phase 4 was based upon the findings of the following previous investigations:

- Peter Brett Associates, Geo-environmental Investigation for Phase III, Green Park, Reading, (August 2002) exploratory hole locations BH103, BHG4, BHG5 and TP204;
- Peter Brett Associates, Earthwork Material Suitability Assessment. Phase III, Green Park, Reading, (November 2005) exploratory hole locations TP222, TP223 and G18;
- Peter Brett Associates, Gas and Water Quality Monitoring Report, Green Park Village, (July 2007) exploratory hole locations G12, G13, G14 and G16; and
- Peter Brett Associates, Report on Ground Investigation for Phase 1A. Green Park Village, (May 2015) exploratory hole locations TP103, TP110, TP117, TP118, TP119 and WS03_2015.

8.4.1. Soil Results – Human Health Risk Assessment

Comparison of soil results has been made to the GAC for a residential with plant uptake end use, as a preliminary worst case scenario. This conservative approach assumes that soft landscaping will be present throughout Phase 4.

Testing for a range of metals and metalloids, total petroleum hydrocarbons (TPH) and polycyclic aromatic hydrocarbons (PAHs) were routinely undertaken within Phase 4 area from Made Ground, the natural strata and soil stockpiles.

Metals and Metalloids

Reviews of the soil results indicate that none of the individual contaminant concentrations of metals exceed the relevant GAC for Phase 4 with the exception of four samples that contained lead and mercury at concentrations above the respective GAC.

Lead

Elevated concentrations of lead were encountered within TP204 (219 mg/kg) within the Topsoil and Alluvium, at a depth of 0.25 m bgl and TP223 (377 mg/kg) within the Made Ground at a depth of 1.00 m bgl. Due to the marginal, isolated occurrence and given the proposed land raise, this exceedance is not considered to pose a significant risk to end users (see Figure 15).

Mercury

Elevated concentrations of mercury were encountered within TP204 (2.30 mg/kg) within the Topsoil and Alluvium, at a depth of 0.25 m bgl and TP223 (2.80 mg/kg) within the Made Ground at a depth of 1.00 m bgl. The exceedances of mercury were made with reference to elemental mercury which is considered a conservative approach (see Figure 14).

When compared against the GAC for inorganic mercury, no exceedance was recorded. Given the low likelihood that the mercury concentration relates entirely to elemental mercury, it is unlikely that the recorded mercury concentration represents a risk to end users at the site.

8.4.2. Total Petroleum Hydrocarbons (TPH)

TPH was tested for in soils routinely across the Phase 4 area. The majority of the testing undertaken was for total TPH, without speciation by carbon chain length or by aliphatic/aromatic type. In some instances, the TPH tested for comprised only extractable petroleum hydrocarbons (EPH) taken as carbon chain lengths C10-40. See Figure 19.

The recorded TPH concentrations were therefore based on the most conservative of the relevant fractions listed within the GAC. No BTEX or MTBE compounds were identified within Phase 4. The TPH results which show concentrations to be above the relevant GAC are shown in Table 22.

Table 22 Potentially Elevated Concentrations of TPHs

ID	Description	Depth of Sample (m bgl)	Concentration (mg/kg)	Strata
TP204	Mineral oil/paraffin	0.25	29	Topsoil and Alluvium
TP222	EPH	0.50	59	Made Ground
TP223	EPH	1.00	428	Topsoil and Alluvium
TP103	EPH	0.17	60	Made Ground

Results for TPH however suggest a potential risk via permeation of buried water supply pipes, and it is anticipated that the water supply company may consider the use of polyethylene pipes to be inappropriate in Phase 4, unless installed within the clean cap materials.

8.4.3. Polycyclic Aromatic Hydrocarbons (PAHs)

Elevated concentrations of PAHs were encountered within TP204 (29 mg/kg) at a shallow depth of 0.25 m bgl, within the Topsoil and Alluvium. Adopting a conservative approach, comparisons of concentrations of total PAH were applied to the GAC for benzo(a)pyrene a surrogate marker (for which the GAC is 5 mg/kg) (see Figure 17).

An elevated concentration of naphthalene was encountered within TP223 (3.63 mg/kg) at a depth of 1.00 m bgl, within the Made Ground. The exceedance recorded was marginally higher than the GAC (2.3 mg/kg). Therefore PAHs are not considered to pose a significant risk to future site users.

8.4.4. Summary TPHs and PAHs Results

The majority of the Phase 4 area will need to be raised by approximately 2 m from the original ground level of 38 mAOD. This platform will effectively act as a cap to the underlying ground.

Therefore elevated concentrations of TPH and PAH are not considered to pose a significant risk to end users. There is the potential risk of ingress of hydrocarbons or other organics into water supply pipes by permeation of plastic pipe materials. The Made Ground from the Phase 4 would not however be likely to be suitable for reuse elsewhere within the site unless deemed appropriate by specific testing and placed beneath buildings, hard surfacing, or an adequate thickness (at least 600 mm) of clean cover material.

Asbestos

During the historic ground investigations no visual evidence of asbestos was recorded within Phase 4. It is noted that minimal analysis of asbestos in soils was undertaken within the Phase (see Figure 12).

8.4.5. Soil Results – Groundwater Risk Assessment

Soil Leachate

A relatively limited dataset of soil leachate data was available for review with testing restricted to the investigations undertaken by PBA in 2015. A single sample tested for leachate was acquired from a soil stockpile within Phase 4 (see Figure 12).

8.4.6. Total Petroleum Hydrocarbons (TPH)

A concentration of TPH exceeded the GAC (10 µg/l) within TP110 (140 µg/l) at a depth of 0.50 mbgl. TPH within the soil leachate have the potential to create risks to controlled waters. It should be noted that the lighter fraction of TPH may have been lost due to volatilisation during the leachate preparation process. Although TPH was identified the risks to controlled waters are not considered to be significant as no exceedances of TPH were identified within the soils results.

The majority of Phase 4 will need to be raised by approximately 2 m from the original ground level of 38 mAOD. This platform will effectively act as a cap to the underlying ground and reduce infiltration. Remediation of Phase 4 with respect to TPH impacts is therefore not considered to be necessary.

8.4.7. Groundwater Results

Adopting a conservative approach, comparison of concentrations of determinands in groundwater has been made to Environmental Quality Standards (EQS) for freshwater and, where these are not available, to UK Drinking Water Standards (DWS).

Metals and Metalloids

Chromium

An elevated concentration of chromium was encountered on one occasion within BHG5 (14 µg/l). The elevated concentration was recorded in several strata including within standpipes installed across the Made Ground and the River Terrace Deposits. Adopting a conservative approach, comparison of

concentrations of chromium was applied to the GAC for chromium VI (3.4 µg/l), should the 95th percentile GAC for total chromium be adopted no exceedances would be recorded. Considering this, the risk is considered to be low and will not be evaluated further as part of this assessment (see Figure 22).

Manganese

Groundwater samples were analysed for manganese in two ground investigations dating back to 2002 and 2005. Elevated concentrations of manganese were encountered within BHG5 (which range from 362 µg/l to 690 µg/l) and BH103 (110 µg/l to 675 µg/l). These are in excess of the GAC for manganese (30 µg/l) (see Figure 26).

The elevated concentrations of manganese occurred in both the natural strata (Alluvium and River Terrace Deposits) and within the Made Ground. Manganese within the groundwater is likely to reflect natural background levels and this has been ascertained by a review of some nearby EA monitoring well data (PBA, 2009).

Ammonia

Elevated concentrations of ammonia were encountered at two locations: BHG5 (ranging from concentrations of 500 µg/l to 700 µg/l) and within BH103 (1100 µg/l). Adopting a conservative approach, comparison of concentrations of ammonia was applied to the GAC of 300 µg/l. The elevated concentrations of ammonia occurred within the shallower groundwater, for instance within the Made Ground and the River Terrace Deposits, although ammonia was also identified in the Lambeth Group (see Figure 20).

A high concentration of ammonia indicates that elevated concentrations of nitrates from fertilisers, for example, may be present. This is likely to be diffuse. The 2009 River Basin Management Plan for the Kennet and Pang catchment suggests that agricultural practice may have detrimentally impacted ground and surface waters. Discussions with the EA should be held to highlight the diffuse nature of this contamination and why site specific remediation would be unlikely to be of benefit.

Nitrate

An elevated concentration of nitrate was encountered within one location: BH103 (300 µg/l). The elevated concentration of nitrate occurred within the shallower groundwater (Alluvium and River Terrace Deposits). No nitrate was identified within the Lambeth Group and the Chalk. Due to the isolated occurrence, nitrate is not considered to pose a significant risk to controlled waters (see Figure 29).

8.4.1 Total Petroleum Hydrocarbons (TPH)

The GAC used to assess TPH concentrations was the UK Drinking Water Standard (10 µg/l), which is a highly conservative approach. TPH was recorded within the Alluvium and the River Terrace Deposits at a concentration in excess of the GAC at one location, BH103 (1000 µg/l).

There is no known specific source for TPH in the groundwater at this location. The recorded concentration of 1000 µg/l was identified using infra-red (IR) methods. IR methods are prone to interferences from non-petroleum sources, and the TPH identified could relate to other organic substances. This result should therefore be treated with caution as it is not likely to represent an existent risk (see Figure 33).

Phenols

No elevated concentrations of phenols in excess of the GAC were identified in groundwater in Phase 4 (see Figure 34).

Ground Gas

Potential sources of ground gas at the Phase 4 area include:

- i. Natural sources such as the decay of organic material in Alluvium, typically around 0.2 to 1.50 m thick;
- ii. Natural sources such as the dissolution of Chalk;
- iii. Decay of anthropogenic material and plant material (e.g. roots) in Made Ground which has been identified at thicknesses of up to 1.80 m; and
- iv. The historic landfills immediately adjacent to the north of Phase 4.

Ground gas monitoring was undertaken by PBA at six locations: G12 (five visits), G13 (five visits), G14 (five visits), G18 (four visits) and WS03_2015 (six visits). BH103 was discounted due to the well being flooded. Monitoring was undertaken at atmospheric pressure conditions ranging from 977 mb to 1020 mb. Table 23 shows the peak ground gas results for Phase 4 and the ground gas plan is illustrated in Figure 40.

Table 23 Phase 4 –Peak Ground Gas Results

ID	Response Zone (m bgl)	Water Level (m bgl)	Peak Carbon Dioxide (CO ₂) Concentration (% v/v)	Peak Methane (CH ₄) Concentration (% v/v)	Gas Flow Rate (l/hr)
G12	0.50 - 4.00	0.55	0.4	0.0	0.5
G13	0.50 - 4.00	1.12	2.0	0.0	0.1
G14	1.00 - 4.45	1.26	2.0	0.0	0.0
G18	0.50 - 2.00	Dry	14	14.5	0.0
WS03_2015	0.10 - 0.80	Dry	2.0	0.0	0.0

Carbon dioxide concentrations were all <5% v/v and methane concentrations were all recorded to be <1% v/v, with the exception of G18 where carbon dioxide concentrations were 14% v/v and methane concentrations were 14.5% v/v. Flow rates were consistently recorded below the detection limit of <0.1 l/hr, with the exception of G12 (0.5 l/hr).

Alluvium is present across most but not all of Phase 4 and may provide some degree of protection to the release of ground gases from the River Terrace Deposits beneath. At G18 alluvium is absent and it is feasible that the elevated concentrations of ground gases recorded at that location arise due to a pathway between the River Terrace Deposits and Made Ground being present when the groundwater elevation falls below the top of the River Terrace Deposits. These conditions are not encountered in other wells and if unsaturated RTD are present elsewhere elevated gas concentrations may also be present.

A worst case scenario was adapted to calculate the potential risks posed by ground gases in Phase 4. The overall gas screening value (GSV) for methane has been calculated to be 0.07 l/hr and for carbon dioxide 0.07 l/hr. This indicates an overall classification of 'Characteristic Situation 2'.

Risks from ground gas are therefore considered to be moderate. From the ground gas monitoring undertaken to date some form of gas protection is required for the buildings and hard-standings, therefore additional ground gas monitoring is required to confirm the previous ground gas results.

8.5 Uncertainties and Gaps in the Information

A moderate risk of ground gas has been identified from the monitoring undertaken to date. Additional rounds of ground gas monitoring are required within Phase 4 (particularly within the vicinity of G18) to comply with current UK guidance for a development which includes residential land use. This must be done from wells which are appropriately designed (e.g. well screen above the water table and in the response zone which is appropriate to monitor). Better quality and more recent data will enable a more efficient design of gas remedial measures. Subsequently, ground gas remedial measures will need to be designed in accordance with current best practice.

Previous soil testing was not always carried out for fully speciated organic compounds (PAHs and TPHs) which renders assessment to current standards difficult. Consequently the methodology adopted as part with this assessment is likely to be overly conservative as the worst case conditions have been considered.

It is considered that insufficient data has been obtained relating to groundwater. In addition, where soil concentrations were found to be high, no leachate analysis was undertaken (excluding TP110), in order to assess the likelihood of the impacted soils affecting water quality. During the historic ground investigations no visual evidence of asbestos was recorded within Phase 4 however this does not preclude its presence and no soils or Made Ground were screened for asbestos.

Further investigation is required to assess risks posed from the migration of contaminants to Phase 4 from offsite sources, including sources from the adjacent Pingemead Industrial Estate (Phase 1 and Phase 2) and the historic landfill sites surrounding Phase 4.

8.6 Risk Evaluation and Conceptual Model

Ramboll has reviewed the historic ground investigation data and in the preceding sections to identify the potential contamination sources, pathways and receptors that are present within Phase 4 in relation to the proposed development. This assessment has been undertaken in order to define the conceptual site model for Phase 4 that is presented Table 24.

The elevated lead, mercury, TPH and PAH concentrations recorded in Phase 4 would be unlikely to pose a risk to human health of future site users given that ground levels are proposed to be raised by approximately 2 m in the affected areas. There is the potential risk of ingress of hydrocarbons or other organics into the water supply pipes by permeation of plastic pipe materials, subsequently potentially affecting future site users, unless installed within the clean imported cap materials.

Made Ground soils excavated from Phase 4 would not be suitable for reuse within residential gardens or areas of soft landscaping unless covered by a suitable clean soil capping, and subject to leachate testing. Control of the release of any substances from excavated Made Ground soils would be required, and could be mitigated by suitable site construction practices. Risks to construction workers could similarly be mitigated by suitable site construction practices in addition to use of standard construction Personal Protective Equipment (PPE).

The elevated metals, ammonia and nitrate concentrations in groundwater recorded at Phase 4 would be unlikely to pose a risk to controlled waters. Potential risks from TPH in groundwater within Phase 4 have been identified. This potential risk should be further considered in the context of detailed quantitative risk assessment in order to ascertain whether the potential risks are likely to be realised, and if required, to derive remedial targets.

Risks from ground gas are considered to be moderate, particularly within G18 where elevated concentrations of carbon dioxide and methane were recorded. From the ground gas monitoring undertaken to date some form of gas protection is required for the buildings and hard-standings. Additional ground gas monitoring is required to confirm the previous ground gas results.

The qualitative hazard assessment identifying potential pollutant linkages has been undertaken below using the source-pathway-receptor framework detailed in Appendix 1. An assessment of the potential significance of each linkage has been made by consideration of the likely magnitude and mobility of the source, the sensitivity of the receptor and nature of the migration/exposure pathways.

Table 24 Phase 4 Conceptual Site Model

Potential Source	Potential Contaminant(s)	Pathway	Potential Receptor	Probability of Risk Being Realised*	Consequence of Risk Being Realised*	Risk Classification*
Made Ground	Asbestos in soils	Inhalation of released fibres	Construction workers	Low likelihood	Severe	Moderate risk
			Adjacent site and phase users	Unlikely	Severe	Moderate/low risk
	Metal and metalloids in soils	Dermal contact	Construction workers	Likely	Mild	Moderate/low risk
		Inhalation of soil dust	Construction workers	Likely	Mild	Moderate/low risk
			Adjacent site and phase users	Low likelihood	Mild	Low risk
		Ingestion of soil	Construction workers	Low likelihood	Mild	Low risk
			Secondary Aquifers (River Terrace Deposits and Lambeth Group)	Likely	Mild (not within a groundwater source protection zone)	Moderate/Low risk I
		Leaching to groundwater and migration in groundwater	Principal Aquifer (Chalk)	Low likelihood	Mild (not within a groundwater source protection zone)	Low risk
			Surface water – ditches	Low likelihood	Mild	Low risk
	TPH and PAH in soil	Dermal contact	Construction workers	Likely	Mild	Moderate/low risk
		Inhalation of soil dust	Construction workers	Likely	Mild	Moderate/low risk
			Adjacent site and phase users	Low likelihood	Mild	Low risk
		Ingestion of soil	Construction workers	Likely	Mild	Moderate/low risk
			Construction workers	Low likelihood	Mild	Low risk
		Inhalation of vapours	Adjacent site and phase users	Unlikely	Mild	Very low risk
			Future site users	Low likelihood	Medium	Moderate/low risk
			Secondary Aquifers (River Terrace Deposits and Lambeth Group)	Likely	Mild (not within a groundwater source protection zone)	Moderate/low risk
		Leaching to groundwater and migration in groundwater	Principal Aquifer (Chalk)	Low	Mild (not within a groundwater source protection zone)	Low risk
			Surface water – ditches	Low likelihood	Mild	Low risk
		Permeation of buried water supply pipes	Future site users	Unlikely	Medium	Low risk

Potential Source	Potential Contaminant(s)	Pathway	Potential Receptor	Probability of Risk Being Realised*	Consequence of Risk Being Realised*	Risk Classification*
Made Ground, Alluvium and Chalk (including the G18 ground gas data)	Ground gases	Migration of gases and build up in confined spaces	Construction workers	Likely	Medium	Moderate risk
			Future site users	Likely	Medium	Moderate risk
			Building structures	Likely	Medium	Moderate risk
		Lateral gas migration caused by development design	Adjacent site and phase users	Unlikely	Medium	Low
			Adjacent building structures	Unlikely	Medium	Low
Offsite historic landfills	Landfill leachate	Downward and subsequently lateral migration of landfill leachate into underlying aquifer	Secondary Aquifers (River Terrace Deposits and Lambeth Group)	Low likelihood	Mild	Low risk
			Principal Aquifer (Chalk)	Unlikely	Mild	Very Low risk
			Surface water	Unlikely	Medium	Low risk
	Ground gas	Gases may migrate into confined spaces such as buildings	Construction workers	Unlikely	Medium	Low risk
			Future site users	Likely	Medium	Moderate risk
			Building structures	Likely	Medium	Moderate risk
Diffuse, regional groundwater contamination	Ammonia and manganese	Vertical and lateral migration via permeable strata	Surface water – ditches	Low likelihood	Mild	Low risk
			Secondary Aquifers (River Terrace Deposits and Lambeth Group)	Low likelihood	Mild (not within a groundwater source protection zone)	Low risk
			Principal Aquifer (Chalk)	Low likelihood	Mild (not within a groundwater source protection zone)	Low risk

Note All risks assume no mitigation in place - for definition of terms see Appendix 1

8.7 Conclusions

Phase 4 is currently unoccupied open ground and had been utilised to stockpile soil materials for raising site levels within Phase 1. The majority of the Phase 4 will need to be raised by around 2 m from the original ground level of 38 mAOD. This platform will effectively act as a cap to the underlying ground. The proposed development of Phase 4 will comprise residential housing with gardens and areas of soft landscaping.

Ramboll has reviewed the previous ground investigation reports undertaken by PBA to identify potential pollutant linkages, and has carried out a risk assessment in line with current published guidance, to determine whether any remedial measures are required. These include the following risks:

- i. Potential for asbestos in Made Ground, as no testing was undertaken;
- ii. Hydrocarbons (PAH and TPH) in soil which may leach and affect water bodies and buried affect water supply pipes;
- iii. Chromium, ammonia, nitrate and TPH in groundwater have been identified;
- iv. The Made Ground soils excavated from Phase 4 would not be suitable for reuse within residential gardens or areas of soft landscaping unless covered by a suitable clean soil capping; and
- v. The overall ground gas risk classification for Phase 4 is 'CS2'. Risks from ground gas are therefore considered to be moderate. From the data obtained to date some form of gas protection is required for the buildings and hard-standings. Additional ground gas monitoring is required to confirm the previous ground gas results.

8.8 Recommendations and Implications for Design, Construction and Project Planning

Further ground investigation to ascertain the quality of groundwater and soil (hydrocarbons and asbestos, in particular) is required within Phase 4.

A moderate gas risk (CS2) has been identified (in particular, G18). Therefore additional ground gas monitoring is required, to comply with current UK guidance. The ground gas monitoring should include for vapours, and it may be prudent to sample and test ground gas to determine its constituents. Given that site levels are proposed to be raised, ground gas monitoring would be required to continue following placement of material to raise ground levels. This is necessary to ascertain whether lateral gas migration has been introduced as a result of the development scheme.

Given the potential TPH concentrations in site soils and groundwater detailed quantitative risk assessment is likely to be required to assess risks to controlled waters.

Depending upon the proposed foundation solution, a piling risk / ground improvement assessment may be required if the solution could introduce pathways for contaminant migration into aquifers beneath the site.

Depending upon the findings of supplementary ground investigations, specific controls for the release of soil dust / asbestos fibres during site works may be required in order to protect ground workers and users of nearby land.

9. ASSESSMENT OF PHASE 5

9.1 Site Setting

Phase 5 is irregular in shape and occupies an area of approximately 2.10 ha at a NGR 469881, 170341. Phase 5 is located on the northern (central) portion of the site and is split by an approximate north-south trending tree-lined ditch as shown in Figures 2 and 9. Phase 5 is bounded by a historic landfill site to north, Trout Lakes to the west and Phases 1, 4, 6 and 7 to the south, east and north respectively.

Early Ordnance Survey mapping (1883) indicates that Phase 5 was undeveloped open land known as "Smallmead Common". By the 1990s the area to the west of the north-south trending ditch was a vehicle storage area belonging to Pingemead Industrial Estate. The area to the east of the (north-south) ditch is undeveloped open land with evidence of re-profiling of the ground and stockpiling. These stockpiles have been utilised for the purpose of land raising at Phase 1.

Information from the various historic ground investigations at Phase 5 indicates that the typical ground conditions comprise Topsoil, Made Ground (approximately 0.4 m to 3.5 m thick), underlain by Alluvium (approximately 0.4 m to 2.2 m thick); River Terrace Deposits (approximately 0.3 m to 4.75 m thick), overlying the Lambeth Group (approximately 5.5 m to 13 m thick), which is turn is underlain by the Chalk (depth unproven).

9.1.1. Soil Stockpiles

Assessment of the soil stockpiles within Phase 5 was made by PBA in 2015 (Green Park Village – Report on Ground Investigation for Phase 1A ref 30158 rev0). It is understood that the vast majority of the soil stockpiles originated from the topsoil removal undertaken from other plots within the Green Park development along with some subsoil materials originating from service trenches, foundations etc.

PBA concluded that on the basis of the soil analysis undertaken up to May 2015 that the soil stockpiles were not adversely impacted by any ground contamination. Therefore this material was considered by PBA suitable for re-use without any remedial treatment and would not pose a hazard to the future site users. It is understood that this assessment has been agreed by the Local Planning Authority.

The soil stockpiles present within Phase 5 were placed within Phase 1 during the end of 2015 and start of 2016 to raise ground levels. During placement, material within the stockpiles was subject to sorting in accordance with the Specification for Earthworks. This sorting included the removal of potentially degradable material such as wood and chalk. Plaster board, metals and plastics were also stipulated within the Specification for Earthworks as being unsuitable for use within placed fill materials.

9.2 Proposals for the Phase 5

Phase 5 will comprise residential housing with gardens, areas of soft landscaping and associated infrastructure. The majority of the Phase 5 will need to be raised by approximately 1.50 m from the original ground level of 39 mAOD. This platform will effectively act as a cap to the underlying ground and is required for flood alleviation purposes. The plans of the proposed development are shown in Drawing PL-MPL-005.

9.3 Summary of Exploratory Locations in Phase 5

Table 25 below provides a summary of exploratory holes advanced within Phase 5, including details of monitoring well installations, groundwater strikes and visual/olfactory evidence of contamination. A 5 m buffer zone has been applied to Phase 5 to capture all the relevant data adjacent the phase.

Table 25 Summary of Exploratory Locations in Phase 5

ID	Depth to Base of Hole (m bgl)	Groundwater Strike (m bgl)	Response Zone (m bgl)	Response Zone Strata	Visual/olfactory Evidence of Contamination
14C_1984	24	No record	-	-	None
BH102	10	No record	2.10 - 4.50	River Terrace Deposits and Lambeth Group	Tarmac, concrete and slight hydrocarbon odour
BHG3	5	1.2	1.00 - 5.00	River Terrace Deposits and Lambeth Group	Occasional brick and gravel flint

ID	Depth to Base of Hole (m bgl)	Groundwater Strike (m bgl)	Response Zone (m bgl)	Response Zone Strata	Visual/olfactory Evidence of Contamination
WS7	4	1.6	-	-	Brick, concrete, gravel flint, concrete, fragments of plastic, plastic bag (1.05 m bgl) and occasional black plant debris
TP225	3.5	Dry	-	-	Fragments of brick, metal and Chalk
TP226	4	Dry	-	-	Brick, flint fragments and organic materials (roots)
TP227	4	Dry	-	-	Brick, flint fragments and organic materials (roots)
TP228	4	Dry	-	-	Brick, flint fragments, timber and black mottling
TP229	3.5	2.3	-	-	None
TP102	1.9	Dry	-	-	Stockpile; occasional brick, concrete, plastic, tarmac, timber and organic materials (roots)

9.4 Evaluation and Assessment of Results

The evaluation and assessment of the results from Phase 5, was based upon the findings of the following previous investigations:

- i. Peter Brett Associates, Geo-environmental Investigation for Phase III, Green Park, Reading, (August 2002) exploratory hole locations 14C_1984, BH102, BHG3 and WS7;
- ii. Peter Brett Associates, Earthwork Material Suitability Assessment. Phase III, Green Park, Reading, (November 2005) exploratory hole locations TP225, TP226, TP227, TP228 and TP229; and
- iii. Peter Brett Associates, Report on Ground Investigation for Phase 1A. Green Park Village, (May 2015) exploratory hole location TP102.

9.4.1. Soil Results – Human Health Risk Assessment

Comparison of soil results has been made to the GAC for a residential with plant uptake end use, as a preliminary worst case scenario. This conservative approach assumes that soft landscaping will be present throughout Phase 5.

Testing for a range of metals and metalloids, TPH and PAHs were routinely undertaken within Phase 5 area from Made Ground, the natural strata and one soil stockpile (TP102).

Metals and Metalloids

Reviews of the soil results indicate that none of the individual contaminant concentrations of metals exceed the relevant GAC for Phase 5 with the exception of a total of three samples that were above the GAC for lead and mercury.

Lead

An elevated lead concentration (303 mg/kg) was encountered in TP228 within the Made Ground, at a depth of 3.50 m bgl. The exceedance recorded was higher than the GAC (200 mg/kg). Due to the marginal, isolated occurrence and the proposed land raise, this exceedance is not considered to pose a significant risk to end users (see Figure 15).

Mercury

Elevated concentrations of mercury were encountered in excess of the GAC at two locations within Phase 5:

- i. BH102 (1.50 mg/kg), within the shallow Topsoil and River Terrace Deposits at a depth of 0.40 m bgl ; and
- ii. TP102 (0.51 mg/kg), within a soil stockpile.

The exceedances of mercury were made with reference to elemental mercury which is considered a conservative approach. When compared against the GAC for inorganic mercury, no exceedances were recorded. Given the low likelihood that the mercury concentration relates entirely to elemental mercury, it is unlikely that the recorded mercury concentration represents a risk to end users at the site (see Figure 14).

9.4.2. Total Petroleum Hydrocarbons (TPH)

TPH were tested for in soils routinely across the Phase 5 area. The majority of the testing undertaken was for total TPH, without speciation by carbon chain length or by aliphatic/aromatic type. In some instances, the TPH tested for comprised only the diesel range organics (DRO) or extractable petroleum hydrocarbons (EPH) taken as carbon chain lengths C10-40.

The recorded TPH concentrations were therefore based on the most conservative of the relevant fractions listed within the GAC. No BTEX or MTBE compounds were identified within Phase 3. The TPH results which show concentrations to be above the relevant GAC are shown in Table 26 (see Figure 19).

Table 26 Potentially Elevated Concentrations of TPHs

ID	Description	Depth of Sample (m bgl)	Concentration (mg/kg)	Strata
BH102	Diesel Range Organics (DRO)	0.40	370	Made Ground
TP226	Extractable Petroleum Hydrocarbons (EPH)	0.50	128	Made Ground
TP228	Extractable Petroleum Hydrocarbons (EPH)	3.50	376	Made Ground

The majority of the Phase 5 area will need to be raised by approximately 1.50 m from the original ground level of 39 mAOD. This platform will effectively act as a cap to the underlying ground.

Therefore elevated concentrations of TPH are not considered to pose a significant risk to end users. The Made Ground from the Phase 5 would not however be likely to be suitable for reuse elsewhere within the site unless deemed appropriate by specific testing and placed beneath buildings, hard surfacing, or an adequate thickness (at least 600 mm) of clean cover material.

Results for TPH suggest a potential risk via permeation of buried water supply pipes, and it is anticipated that the water supply company may consider the use of polyethylene pipes to be inappropriate at Phase 5.

9.4.3. Asbestos

During the historic ground investigations no visual evidence of asbestos was recorded within Phase 5. It is noted that minimal analysis of asbestos in soils was undertaken within the Phase (see Figure 12).

9.4.4. Soil Results – Groundwater Risk Assessment

Soil Leachate

No soil samples were scheduled for leachate analysis during the historic ground investigations within Phase 5. No free phase hydrocarbons were identified from the investigations.

Groundwater Results

Adopting a conservative approach, comparison of concentrations of determinands in groundwater has been made to Environmental Quality Standards (EQS) for freshwater and, where these are not available, to UK Drinking Water Standards (DWS).

Metals and Metalloids

Chromium

Elevated concentrations of chromium were encountered within BH102 (5 µg/l) and 14C_1984 (13 µg/l).

The elevated concentrations were recorded in several strata including within standpipes installed across the Made Ground, the River Terrace Deposits and the Chalk. Adopting a conservative approach, comparison of concentrations of chromium was applied to the GAC for chromium VI (3.4 µg/l), should the 95th percentile GAC for total chromium be adopted no exceedances would be recorded. Considering the risk is considered to be low and will not be evaluated further as part of this assessment. See Figure 22.

Copper

An isolated occurrence of copper was encountered within BH102 (21 µg/l) in 2002. Comparisons of concentrations of copper were applied to the GAC (10 µg/l). The elevated concentrations were recorded in several strata including within standpipes installed across the Made Ground and the River Terrace Deposits. Considering the isolated and marginal nature of the exceedance, it is unlikely that the recorded copper concentration represents a risk to controlled waters or human health (see Figure 23).

Manganese

Elevated concentrations of manganese were encountered within two locations: BH102 with concentrations which range from 133 µg/l to 237 µg/l and within 14C_1984 which range from 69 µg/l and 72 µg/l. Comparisons of concentrations of manganese were applied to the GAC (30 µg/l) (see Figure 26).

The elevated concentrations of manganese occurred in both the natural strata (River Terrace Deposits and the Chalk) and within the Made Ground. Manganese within the groundwater is likely to reflect natural background levels and this has been ascertained by a review of some nearby EA monitoring well data (PBA, 2009).

Ammonia

Adopting a conservative approach, comparisons of concentrations of ammonia were applied to the GAC of 300 µg/l. The elevated concentrations of ammonia occurred within:

- i. The shallower groundwater for instance within the Made Ground and the River Terrace Deposits in BH102; 500 µg/l to 1300 µg/l; and
- ii. Within the Chalk in 14C_1984; 400 µg/l to 600 µg/l.

The high concentrations of ammonia indicate that elevated concentrations of nitrates from fertilisers, for example, may be present. This is likely to be diffuse. Discussions with the EA should be held to

highlight the diffuse nature of this contamination and why site specific remediation would be unlikely to be of benefit (see Figure 20).

9.4.1 Total Petroleum Hydrocarbons (TPH)

The GAC used to assess TPH concentrations was the UK Drinking Water Standard (10 µg/l), which is a highly conservative approach. Elevated concentrations of TPH were recorded in 2002 at BH102 in groundwater of the River Terrace Deposits. The recorded concentration of 1000 µg/l was identified using infra-red (IR) methods (see Figure 33). IR methods are prone to interferences from non-petroleum sources, and the TPH identified could relate to other organic substances. This result should therefore be treated with caution as it is not likely to represent an existent risk

9.4.2 Polycyclic Aromatic Hydrocarbons (PAHs)

An isolated occurrence of PAH was encountered within BH102 (0.37 µg/l) in 2005 in excess of the GAC. The occurrence of PAH occurred in both the natural strata (River Terrace Deposits) and within the Made Ground (see Figure 32).

9.4.3 Summary TPHs and PAHs Results

In 2002 the ground investigation undertaken by PBA recorded elevated concentrations of TPH and PAHs within the shallow groundwater (Made Ground and River Terrace Deposits) in BH102. A slight hydrocarbon odour was also noted during drilling. No soil leachate testing was undertaken during the 2002 ground investigation. Consequently, Ramboll would recommend that further assessment should be undertaken at this location, specifically for these contaminants.

Phenols

No elevated concentrations of phenols in excess of the GAC were identified in groundwater in the Phase 5 (see Figure 34).

Ground Gas

Potential sources of ground gas at the Phase 5 area include:

- i. Natural sources such as the decay of organic material in Alluvium, typically around 0.4 to 2.2 m thick;
- ii. Natural such as from the dissolution of Chalk;
- iii. Decay of anthropogenic material and plant material (e.g. roots) in Made Ground which has been identified at thicknesses of up to 3.5 m;
- iv. Degradation of shallow hydrocarbon contamination in soil and/or groundwater; and
- v. The historic landfills immediately to the north of of Phase 5.

Ground gas monitoring was undertaken by PBA at one location BHG3 (six visits). BH102 was discounted due to the well being flooded. From the limited ground gas information available carbon dioxide concentrations were all <5% v/v and methane concentrations were all recorded to be <1% v/v. The maximum recorded flow rate was 1.2 l/hr. Monitoring was undertaken at an atmospheric pressure of 977 mb.

Table 27 shows the peak ground gas results for Phase 5 and the ground gas plan is illustrated in Figure 40.

Table 27 Phase 5 –Peak Ground Gas Results

ID	Response Zone (m bgl)	Water Level (m bgl)	Peak Carbon Dioxide (CO ₂) Concentration (% v/v)	Peak Methane (CH ₄) Concentration (% v/v)	Gas Flow Rate (l/hr)
BHG3	1.00 - 5.00	1.12	0.5	0.0	1.2

Based on only one set of ground gas monitoring results a worst case scenario was adopted to calculate the potential risks posed by ground gases at Phase 5. The overall gas screening value (GSV) for methane has been calculated to be 0.00 l/hr and for carbon dioxide 0.01 l/hr. This indicates an overall classification of 'Characteristic Situation 1'. Risks from ground gas are therefore considered to be low.

9.5 Uncertainties and Gaps in the Information

Although no significant gas risk has been identified from the monitoring undertaken to date, additional rounds of ground gas monitoring are required within Phase 5 to comply with current UK guidance for a development which includes residential land use. This must be done from wells which are appropriately designed (e.g. well screen above the water table and in the response zone which is appropriate to monitor). Better quality and more recent data will enable a more efficient design of any potential gas remedial measures. Subsequently, should Phase 5 require remedial measures these will need to be designed in accordance with current best practice.

Previous soil testing was not always carried out for fully speciated organic compounds (PAHs and TPHs) which renders assessment to current standards difficult. Consequently the methodology adopted as part with this assessment is likely to be overly conservative as the worst case conditions have been considered.

The typical exploratory hole spacing within Phase 5 is considered to be unsuitable for ground gas monitoring, for instance gaps in the southern portion of Phase 5. There is limited evidence from the historic ground investigations undertaken to date which assess the risks from the former vehicle storage area, particularly in the vicinity of BH102, where no soil leachate testing was undertaken.

Insufficient data has been obtained relating to groundwater quality. In addition, where soil concentrations were found to be high, no leachate analysis was undertaken, in order to assess the likelihood of the impacted soils affecting water quality. During the historic ground investigations no visual evidence of asbestos was recorded within Phase 5 however this does not preclude its presence and no soils or Made Ground were screened for asbestos.

Further investigation is required to assess risks posed from the migration of contaminants to Phase 5 from offsite sources, including sources from the adjacent Pingemead Industrial Estate (Phase 1) and the historic landfill site north of Phase 5.

9.6 Risk Evaluation and Conceptual Model

Ramboll has reviewed the historic ground investigation data and in the preceding sections to identify the potential contamination sources, pathways and receptors that are present within Phase 5 in relation to the proposed development. This assessment has been undertaken in order to define the conceptual site model for Phase 5 that is presented Table 28.

The elevated lead, mercury and TPH concentrations recorded in Phase 5 would be unlikely to pose a risk to human health of future site users given that ground levels are proposed to be raised by approximately 1.50 m in the affected area. There is the potential risk of ingress of hydrocarbons or other organics into the water supply pipes by permeation of plastic pipe materials, subsequently potentially affecting future site users.

Made Ground soils excavated from Phase 5 would not, however, be suitable for reuse within residential gardens or areas of soft landscaping unless covered by a suitable clean soil capping, and subject to leachate testing. Control of the release of any substances from excavated Made Ground soils would be required, and could be mitigated by suitable site construction practices. Risks to construction workers could similarly be mitigated by suitable site construction practices in addition to use of standard construction Personal Protective Equipment (PPE).

Potential risks from TPH and PAH in groundwater may affect the underlying aquifers and nearby surface water bodies (ditches and the Trout Lakes within the site). These potential risks should be further considered in the context of detailed quantitative risk assessment in order to ascertain whether the potential risks are likely to be realised, and if required, to derive remedial targets.

The qualitative hazard assessment identifying potential pollutant linkages has been undertaken below using the source-pathway-receptor framework detailed in Appendix 1. An assessment of the potential significance of each linkage has been made by consideration of the likely magnitude and mobility of the source, the sensitivity of the receptor and nature of the migration/exposure pathways.

Table 28 Phase 5 Conceptual Site Model

Potential Source	Potential Contaminant (s)	Pathway	Potential Receptor	Probability of Risk Being Realised*	Consequence of Risk Being Realised*	Risk Classification*
Made Ground	Asbestos in soils	Inhalation of released fibres	Construction workers	Low likelihood	Severe	Moderate risk
			Adjacent site and phase users	Unlikely	Severe	Moderate/low risk
	Metal and metalloids in soils	Dermal contact	Construction workers	Likely	Mild	Moderate/low risk
		Inhalation of soil dust	Construction workers	Likely	Mild	Moderate/low risk
			Adjacent site and phase users	Low likelihood	Mild	Low risk
		Ingestion of soil	Construction workers	Low likelihood	Mild	Low risk
		Leaching to groundwater and migration in groundwater	Secondary Aquifers (River Terrace Deposits and Lambeth Group)	Likely	Mild (not within a groundwater source protection zone)	Moderate / low risk
			Principal Aquifer (Chalk)	Low likelihood	Mild (not within a groundwater source protection zone)	Low risk
			Surface water – Trout Lakes and ditches	Low likelihood	Mild	Low risk
	TPH and PAH in soil	Dermal contact	Construction workers	Likely	Mild	Moderate/low risk
		Inhalation of soil dust	Construction workers	Likely	Mild	Moderate/low risk
			Adjacent site and phase users	Low likelihood	Mild	Low risk
		Ingestion of soil	Construction workers	Likely	Mild	Moderate/low risk
		Inhalation of vapours	Construction workers	Low likelihood	Mild	Low risk
			Adjacent site and phase users	Unlikely	Mild	Very low risk
			Future site users	Low likelihood	Medium	Moderate/low risk

Potential Source	Potential Contaminant (s)	Pathway	Potential Receptor	Probability of Risk Being Realised*	Consequence of Risk Being Realised*	Risk Classification*
		Leaching to groundwater and migration in groundwater	Secondary Aquifers (River Terrace Deposits and Lambeth Group)	Likely	Mild (not within a groundwater source protection zone)	Moderate / low risk
			Principal Aquifer (Chalk)	Low likelihood	Mild (not within a groundwater source protection zone)	Low risk
			Surface water – Trout Lakes and ditches	Low likelihood	Mild	Low risk
		Permeation of buried water supply pipes	Future site users	Unlikely	Medium	Low risk
Made Ground, Alluvium and Chalk	Ground gases	Migration of gases and build up in confined spaces	Construction workers	Unlikely	Medium	Low risk
			Future site users	Low likelihood	Medium	Moderate/low risk
			Building structures	Low likelihood	Medium	Moderate/low risk
		Lateral gas migration caused by development design	Adjacent site and phase users	Unlikely	Medium	Low risk
			Adjacent building structures	Unlikely	Medium	Low risk
Historic car compound (onsite)	TPH, PAH, fuels, hydraulic oils, lubricating oils and metals	Dermal contact	Construction workers	Likely	Mild	Moderate/low risk
		Inhalation of soil dust	Construction workers	Likely	Mild	Moderate/low risk
			Adjacent site and phase users	Low likelihood	Mild	Low risk
		Inhalation of vapours	Construction workers	Low likelihood	Mild	Low risk
			Adjacent site and phase users	Unlikely	Mild	Very low risk
			Future site users	Low likelihood	Mild	Low risk
		Migration in groundwater	Secondary Aquifers (River Terrace Deposits and Lambeth Group)	Likely	Mild (not within a groundwater source protection zone)	Moderate/low risk
			Principal Aquifer (Chalk)	Low	Mild (not within a groundwater source protection zone)	Low risk
		Surface water	Surface water – Trout Lakes and ditches	Likely	Mild	Moderate/low risk
		Permeation of buried water supply pipes	Future site users	Unlikely	Medium	Low risk

Potential Source	Potential Contaminant (s)	Pathway	Potential Receptor	Probability of Risk Being Realised*	Consequence of Risk Being Realised*	Risk Classification*
Offsite historic landfills	Landfill leachate	Downward and subsequently lateral migration of landfill leachate into underlying aquifer	Secondary Aquifers (River Terrace Deposits and Lambeth Group)	Low likelihood	Mild (not within a groundwater source protection zone)	Low risk
			Principal Aquifer (Chalk)	Low likelihood	Mild (not within a groundwater source protection zone)	Low risk
		Surface water	Surface water – Trout Lakes and ditches	Unlikely	Medium	Low risk
	Ground gas	Gases may migrate into confined spaces such as buildings	Construction workers	Unlikely	Medium	Low risk
			Future site users	Low likelihood	Medium	Moderate/low risk
			Building structures	Low likelihood	Medium	Moderate/low risk
Groundwater in the Made Ground and River Terrace Deposits at BH102	TPH and PAH	Migration in groundwater	Secondary Aquifers (River Terrace Deposits and Lambeth Group)	Likely	Mild (not within a groundwater source protection zone)	Moderate/low risk
Diffuse, regional groundwater contamination	Ammonia and manganese	Vertical and lateral migration via permeable strata	Surface water – Trout Lakes and ditches	Low likelihood	Mild	Low risk
			Secondary Aquifers (River Terrace Deposits and Lambeth Group)	Low likelihood	Mild (not within a groundwater source protection zone)	Low risk
			Principal Aquifer (Chalk)	Low likelihood	Mild (not within a groundwater source protection zone)	Low risk

Note All risks assume no mitigation in place - for definition of terms see Appendix 1

9.7 Conclusions

Phase 5 was historically used as a vehicle storage area (only within west of ditch only) and later utilised to stockpile soil materials for raising site levels within Phase 1. Currently Phase 5 is undeveloped land. The majority of the Phase 5 will need to be raised by around 1.50 m from the original ground level of 39 mAOD. This platform will effectively act as a cap to the underlying ground. The proposed development of Phase 5 will comprise residential housing with gardens and areas of soft landscaping.

Ramboll has reviewed the previous ground investigation reports undertaken by PBA to identify potential pollutant linkages, and has carried out a risk assessment in line with current published guidance, to determine whether any remedial measures are required. These include the following risks:

- i. Potential for asbestos in Made Ground, as no testing was undertaken;
- ii. Hydrocarbons in soil which may migrate and affect water bodies and buried water supply pipes;
- iii. Chromium, copper, manganese, nickel, ammonia, nitrate and TPH in groundwater have been identified;
- iv. The Made Ground soils excavated from Phase 5 would not be suitable for reuse within residential gardens or areas of soft landscaping unless covered by a suitable clean soil capping; and
- v. No significant gas risk has been identified from the monitoring undertaken to date, however the gas risk assessment was based one location within Phase 5. Additional rounds of ground gas monitoring are required to comply with current UK guidance.

9.8 Recommendations and Implications for Design, Construction and Project Planning

Further ground investigation to ascertain the quality of groundwater and soil (hydrocarbons and asbestos, in particular) is required within Phase 5 and specifically in the vicinity of BH102 where evidence of historical hydrocarbon contamination has been identified.

Although no significant ground gas risk (CS1) has been identified, additional ground gas monitoring is required, to comply with current UK guidance. The ground gas monitoring should include for vapours, and it may be prudent to sample and test ground gas to determine its constituents. Given that site levels are proposed to be raised, ground gas monitoring would be required to continue following placement of material to raise ground levels. This is necessary to ascertain whether lateral gas migration has been introduced as a result of the development scheme.

In the absence of specific testing beneath potential point sources of contamination, such as the vehicle storage area belonging to Pingemead Industrial Estate, further investigation is required within this area. Allowance ought to be made for localised removal of hotspots of soils impacted by contamination. Detailed quantitative risk assessment is likely to be required to assess risks to controlled waters, and localised remediation may be necessary.

Depending upon the proposed foundation solution, a piling risk / ground improvement assessment may be required if the solution could introduce pathways for contaminant migration into aquifers beneath the site.

Depending upon the findings of supplementary ground investigations, specific controls for the release of soil dust / asbestos fibres during site works may be required in order to protect ground workers and users of nearby land. The Made Ground soils excavated from Phase 5 would not be suitable for reuse within residential gardens or areas of soft landscaping unless covered by a suitable clean soil capping.

10. ASSESSMENT OF PHASE 6

10.1. Site Setting

Phase 6 is irregular in shape and occupies an area of approximately 3.24 ha. At the time of preparing this report the Phase was unoccupied scrub land, generally free of significant vegetation with a rough surface with frequent plastic, metal, brick, concrete and tarmac fragments, giving an indication of its potentially contaminative historical usage.

Phase 1C West is present to the southeast of Phase 6 with Phase 7 to the northeast. Both these phases have a historical and current site use in accord with Phase 6 and are discussed below.

Early Ordnance Survey mapping (1883) indicates that Phases 1C West, 6 and 7 were undeveloped open land surrounded by marshes with localised ground workings (suspected borrow pits) located in the western part of the Phase. These ceased to be marked by early 1900 mapping suggesting infilling had taken place.

More large scale mineral extraction took place at the Trout Lakes to the east of the Phase which is marked on the 1972 map. Further extraction was undertaken within the Trout Lakes in the late 1990s when it is reported by PBA that material from the Lambeth Group was won as an engineering fill for Phase 1 of the wider Green Park commercial development. By 2008 the Trout Lakes were re-configured into their current layout with a large lake formed through the merging of the north eastern, south eastern and south western water bodies and a smaller water body formed by a north western lake. The northern part of the latter lake is shown on mapping to be infilled with the southern part proposed to be infilled as part of the development proposals.

Within the Phase 6 area a historic waste transfer and treatment facility, known as Clembins Ltd, was present and was operated by Mr A L Clements under licence 54/12/4/361. It was noted by PBA that mounds of stockpiled material, skips and site buildings were present until 2007, when operations at this facility ceased. According to the EA this portion of land is understood to be part of an active landfill referred to as Burghfield landfill and also a historic landfill referred to as Burghfield Area D under licence reference 86253. Prior to this it is understood that a local farmer used the area to deposit materials of unknown origin. Currently the site is disused and derelict, formed of mostly level scrub land.

The area has been subject to a number of ground investigations. The range of exploratory holes undertaken and a description of visual and olfactory evidence of contamination encountered is summarised in Section 10.3.

The geology underlying Phase 6 comprises between 0.7 m and 4.7 m of Made Ground overlying Alluvium (0.4 m to 1.3 m thick), River Terrace Deposits (0.2 m to 2.0 m thick), Lambeth Group (3.6 m to 4.7 m thick) and an unproven thickness of the White Chalk subgroup.

Groundwater monitoring has been undertaken within the majority of historical ground investigations within Phase 6. Generally shallow groundwater was encountered at the Made Ground/River Terrace Deposits interface between 0.4 m and 4.2 m bgl (typically 2.5 m bgl) and within the Lambeth Group between 6.0 m and 8.9 m bgl (typically 7.4 m bgl). Groundwater flow directions are generally in keeping with site wide trends aside from within the River Terrace Deposits where flow was recorded to the east-southeast (site wide RTD flow is towards the northeast). PBA attributed this local variation to the variable thickness of water bearing River Terrace Deposits due to historical mineral extraction, pumping and discharge at the nearby Smallmead landfill and the presence of an impermeable barrier around the landfill.

Permeability tests have historically been carried out in Phase 6 in BH2009/04 and BH2009/07 within the upper Lambeth Group at 10 m bgl which indicated soils with a very lower permeability with results of 9.4×10^{-8} m/s and 6.4×10^{-8} m/s respectively.

10.2. Proposals for the Phase 6

Phase 6 will comprise commercial offices with areas of soft landscaping, associated infrastructure and a multi decked car park. Generally ground levels are proposed to be raised from between +38.5 mAOD and 39.9 mAOD (more commonly 39.5 mAOD) to 40.2 mAOD resulting in the placement of between 0.7 and 1.7 m of fill upon existing ground levels.

The outline plans also indicate the infilling of the north western portion of the Trout Lakes which will involve raising levels from approximately 35 mAOD to 40.2 mAOD (~5.2 m of fill).

Phase 1C West and Phase 7 both comprise access roads and areas of soft landscaping open space.

10.3. Summary of Exploratory Locations in Phase 6

Table 29 below provides a summary of exploratory holes advanced within the Phase 6 area (also encompassing Phase 1C west and 7), including details of monitoring well installations, groundwater strikes and visual/olfactory evidence of contamination. A 5 m buffer zone has been applied to Phase 6 to capture all the relevant data adjacent the phase.

An exploratory hole plan showing these locations is contained in Figure 10 and 11.

Table 29 Summary of Exploratory Locations in Phase 6

ID	Depth to Base of Hole (m bgl)	Groundwater Strike (m bgl)	Response Zone (m bgl)	Response Zone Strata	Visual/Olfactory Evidence of Contamination
Phase 6					
TP2	2.2	1.5	-	-	Brick, concrete blocks, plastic (plastic pipe), rubber hosing, fibres material (some odour) (0.50 m bgl)
TP6	3	1.3	-	-	Brick, concrete rubble, plastic, fabric, plastic pipe and wood
BHG1	5.1	3.2	1.00 - 5.10	Made Ground and Alluvium and River Terrace Deposits and Lambeth Group	Brick, fragments of wood, ceramic, organic material and a slight organic odour
TP201	4.1	0.9	-	-	Brick, flint, ceramic, glass, occasional fragments of plastic, wood, paper, metal, bituminous material. At 0.70 m bgl; oily black liquid
TP230	4	Dry	-	-	Occasional brick, plastic and organic materials (roots)
TP231	4.2	3.5	-	-	Occasional decaying material and a large tree trunk at 2.00 m bgl
BH112	10	3.10 and 8.9	8.50 - 9.50	Lambeth Group	Large fragments of timber, brick, concrete, gravel, Chalk, black ash and wood
BHA	5.45	3.7	-	-	Cobbles of brick, concrete, wood, metal mesh, paper, plastic, timber, pockets of black gravel, pieces of nail and inclusions of dark brown black clay
BHB	5.5	2.3	1.00 - 5.50	Made Ground and Alluvium and River Terrace Deposits	Brick, concrete, flint and occasional black staining and pockets of ash
BHC	4.5	4.2	1.00 - 4.50	Made Ground and Lambeth Group	Fragments of bricks, wood and concrete
BHE	5.5	No record	1.00 - 5.50	Made Ground and Alluvium and River Terrace Deposits and Lambeth Group	Brick, concrete and flint
TPA	1.6	1.2	-	-	Black/brown sand, brick, concrete, fragments of

ID	Depth to Base of Hole (m bgl)	Groundwater Strike (m bgl)	Response Zone (m bgl)	Response Zone Strata	Visual/Olfactory Evidence of Contamination
					wood, metal mesh, paper, plastic, timber and occasional pockets of black gravel
TPB	3.4	1.2	-	-	Brick, concrete rubble, fragments of wood, plastic, pieces of tile, wire, plastic sheets, brown/black gravelly sand and black clay,
TPC	3.1	0.3	-	-	Brick, concrete rubble, wood, plastic, Chalk, organic materials (branches and decomposing leaf matter)
TPD	2.9	0.6	-	-	Brick, concrete, wood chippings, plastic and nylon
TPH	2.7	2.3	-	-	Brick, plastic, timber and clinker
TPI	4.3	3.4	-	-	Occasional brick and timber debris
TPJ	4.6	No record	-	-	Bricks, plastic, glass, Chalk and decomposed plant debris
TPK	4.7	No record	-	-	Brick, flint, concrete, timber, plastic and nylon sheets
TPL	3.4	No record	-	-	Brick, concrete, timber, plastic, metal and nylon bags
WS1_2007	3	1.6	1.00 - 2.00	Made Ground and Alluvium and River Terrace Deposits	Concrete
WS2_2007	3	1.2	0.50 - 1.50	Made Ground and Alluvium and River Terrace Deposits	Brick, concrete, glass, wood board and plastic
WS3_2007	2.8	No record	1.00 - 2.00	Alluvium and River Terrace Deposits	Concrete, brick and flint. At between 0.19 m bgl and 0.30 m bgl; Sight hydrocarbon odour
WS7_2007	2.8	No record	1.00 - 2.80	Made Ground and Alluvium and River Terrace Deposits	Intact bricks, concrete, black bituminous material, road stone gravel, fragments of glass, plastic, Chalk and wood
TPA10	2.2	Dry	-	-	Whole bricks, concrete, ceramics, glass, wood, plastic, metal and textiles Possible landfill material and a strong landfill odour
TPA11	2.2	0.9	-	-	Whole bricks, concrete, plastic, textile, wood and flint
TPA12	1.9	Dry	-	-	Bricks, flint, concrete, occasionally stained black gravelly organic clay and

ID	Depth to Base of Hole (m bgl)	Groundwater Strike (m bgl)	Response Zone (m bgl)	Response Zone Strata	Visual/Olfactory Evidence of Contamination
					plant remains
TP302	2.5	1.8	-	-	Brick, concrete, ceramics, metal fragments, flint and Chalk At between 1.20 m bgl to 1.80 m bgl; pockets of peat and an organic odour
TP303	2.8	2.2	-	-	Bricks, concrete, flint, wood, metal, ceramics and peaty clay
TP307	2.8	2.5	-	-	Concrete, brick, plastic, wood, metal, Chalk, large organic and wood remains and peat pockets
TP308	2.5	1.2	-	-	Bricks, concrete, ceramics, flint, wood, glass, metal, plastic and occasionally stained black clay
TP309	3	Dry	-	-	Bricks, concrete, plastic, metal, rubber, wood fragments, Chalk and flint At between 0.20 m bgl to 0.40 m bgl; hydrocarbon/solvent odour
TP310	2.8	1.7	-	-	Bricks, concrete, chalk, flint, metal, wood and plastic fragments At between 0.20 m bgl to 2.50 m bgl: slight organic odour At between 2.50 m bgl to 2.80 m bgl: organic odour
TP311	3	2.5	-	-	Brick, concrete, plastic, wood, ceramics, textiles, metal, Chalk, flint and occasional tyre fragments At between 1.20 m bgl to 2.50 m bgl; slight organic odour
TP312	3	Dry	-	-	Bricks, concrete, flint, plastic, wood, textile, glass, rare organics, timber and Chalk
TP313	2.9	0.3	-	-	Wood chipping, bricks, flint, plastic and black sand pockets Between 1.30 m bgl to 2.30 m bgl; organic odour
TP314	2.9	1.7	-	-	Brick, concrete and stained black slightly gravelly clay

ID	Depth to Base of Hole (m bgl)	Groundwater Strike (m bgl)	Response Zone (m bgl)	Response Zone Strata	Visual/Olfactory Evidence of Contamination
					Between 0.40 m bgl to 0.60 m bgl: Slight organic odour Between 1.00 m bgl to 1.40 m bgl; organic odour
RGPWS02	5	1.3	-	-	Carbonaceous debris, bricks, tile, wood, glass, concrete and unknown waste products
BH1_2007_2009	14.35	2	3.00 - 5.50	River Terrace Deposits	Bricks and concrete
BH2009/01	20	3.2	17.70 - 20.00	Chalk	Bricks, concrete, flint, plastic, wood, metal fragments, tile and pockets of peat
BH2009/02	6	1.8	2.70 - 5.00	River Terrace Deposits	Bricks, wood fragments, flint, fabric and organic materials (roots)
BH2009/04	10	2.7 and 7.8	7.80 - 10.00	Lambeth Group	Bricks, plastics, glass, metals and flint
BH2009/05	20.2	0.4 and 7.4	17.70 - 20.20	Chalk	Bricks, concrete, bitumen, plastic, wood and organic clay with pockets off fibrous peat
TP6006	2.5	2.2	-	-	Brick, concrete, flint, glass, plastic, wood, metal and some evidence of burnt materials Possible landfill material and between 0.40 m bgl to 0.50 m bgl a layer of bitumen coated stone chippings
TP6007	2.2	Dry	-	-	Bricks, concrete, flint, wood, wood chippings, plastic, metal, glass, pipes and rare plant remains
TP6008	2.5	2.4	-	-	Wood chippings, brick, plastic fragments, tarmac and plastic
TP6009	2.7	Dry	-	-	Bricks, concrete, metal, wood, glass, fabric, flint and plant remains
TP6010	2.1	Dry	-	-	Brick, concrete, flint, plastic, wood, metal, tarmacadam, textiles and rare peat pockets
TP6011	2.1	1.9	-	-	Brick, concrete, flint, plastic, wood, metal, tarmacadam, textiles and rare peat pockets
Phase 1C West					
TP6001	4.2	1	-	-	Bricks, concrete, flints, wood, plastic, ceramics and plant remains Between 0.40 m bgl and

ID	Depth to Base of Hole (m bgl)	Groundwater Strike (m bgl)	Response Zone (m bgl)	Response Zone Strata	Visual/Olfactory Evidence of Contamination
					0.50 m bgl; bitumen/slight hydrocarbon odour
TP6002	4	0.7	-	-	Bitumen (tarmacadam), whole bricks, concrete , frequent plastic, wood, ceramics and rare plant remains Between 0.10 m bgl and 0.50 m bgl; oily with hydrocarbon odour
TP6003	4.5	4.2	-	-	Bitumen (tarmacadam), bricks, concrete , frequent plastic, wood, metal and rare plant remains Between 0.10 m bgl and 0.40 m bgl; slight chemical odour
TP6004	4.5	Dry	-	-	Bitumen (tarmacadam), bricks, concrete , frequent plastic, flint, wood, metal and rare plant remains
TP6005	4.2	Dry	-	-	Bitumen (tarmacadam), bricks, concrete , frequent plastic, flint, wood, tiles, metal and rare plant remains
WS6_2007	3.0	1.6	1.00 to 3.00	Made Ground and River Terrace Deposits	Brick, concrete and tile.
WS8_2007	5.0	Dry	1.00 to 4.00	Made Ground and River Terrace Deposits	Brick, concrete, tile and wood.
TPA08	2.5	Dry	-	-	Bitumen (tarmacadam), bricks, concrete, frequent plastic, wood and metal.
TPA09	1.6	2.0	-	-	Bitumen (tarmacadam), bricks, concrete, frequent plastic, wood, glass, ceramics and metal.
TP1	2.4	2.0	-	-	-
TP8	1.8	1.2	-	-	-
TP301	2.5	1.8	-	-	Bitumen (tarmacadam), bricks, concrete, frequent plastic, wood, glass, ceramics and metal. Organic odour between 0.55 mbgl and 1.2 mbgl.
BHF	4.5	1.6	1.00 to 4.50	Made Ground and Alluvium and River Terrace Deposits	-
BH2009/06	4.4	2.5	2.80 to 4.00	Made Ground and River Terrace	-

ID	Depth to Base of Hole (m bgl)	Groundwater Strike (m bgl)	Response Zone (m bgl)	Response Zone Strata	Visual/Olfactory Evidence of Contamination
				Deposits and Lambeth Group	
BH2009/07	10.0	4.2 and 6.0	6.80 to 10.0	Made Ground and River Terrace Deposits and Lambeth Group	Bitumen (tarmacadam), bricks, concrete, frequent plastic, wood, glass, ceramics and metal. Slight peaty odour at 2.5m.
Phase 7					
BHG2	5.0	-	1.00 to 5.00	Made Ground and Alluvium and River Terrace Deposits	Slight organic odour between 0.1 mg/l and 1.7 mg/l.

10.4. Evaluation and Assessment of Results

The evaluation and assessment of the results from Phase 1C West, Phase 6 and Phase 7 is based upon the findings of the following previous investigations:

- i. Peter Brett Associates, Interim Report of Ground Investigation for Clembins Waste Transfer Station, Reading, Berkshire (June, 2001) exploratory hole locations TP1, TP2, TP6 and TP8;
- ii. Peter Brett Associates, Geo-environmental Investigation for Phase III, Green Park, Reading, (August 2002) exploratory hole locations BHG1 and TP201;
- iii. Peter Brett Associates, Earthwork Material Suitability Assessment. Phase III, Green Park, Reading, (November 2005) exploratory hole locations TP230 and TP231;
- iv. Peter Brett Associates, Gas and Water Quality Monitoring Report, Green Park Village, (July 2007) exploratory hole location BH112;
- v. Peter Brett Associates, Phase 1 and 2 Ground Condition Assessment, Clembins Waste Transfer Station Site, Reading (September, 2007) exploratory hole locations BH1A, BHB; BHC, BHE, BHF, TPA, TPB, TPC, TPD, TPH, TPI, TPJ, TPK, THP, WS1_2007, WS2_2007, WS3_2007, WS6_2007, WS7_2007 and WS8_2007.
- vi. Peter Brett Associates, Report on Ground Condition Assessment – Phase 1 and 2. Green Park Station – Temporary Access Road and Park (February 2009) exploratory hole locations TPA08, TPA09, TPA10, TPA11, TPA12, TP301, TP302, TP303, TP307, TP308, TP309, TP310, TP311, TP312, TP313, TP314, RGPWS02, BH1_2007-2009, BH2009/01, BH2009/02, BH2009/04, BH2009/05, BH2009/06 and BH2009/07; and
- vii. Peter Brett Associates, Report on Supplementary Phase 2 Ground Investigations and Tier 2 Risk Assessment. Green Park Railway Station, Reading (October 2009) exploratory hole locations TP6001, TP6002, TP6003, TP6004, TP6005, TP6006, TP6007, TP6009, TP6010 and TP6011.

10.4.1. Soil Results – Human Health Risk Assessment

As the Phase 6 area of the site is proposed for redevelopment for a commercial end use, the concentrations of substances in soil have been assessed by comparison to GAC for a commercial / industrial end use (see Appendix 2).

Testing for a range of metals, metalloids, inorganics and organics was undertaken within Phase 1C West, Phase 6 and Phase 7 and included samples of Made Ground and natural strata (Alluvium, River Terrace Deposits, Lambeth Group and the Chalk).

The evaluation of risk based upon the results of soil testing in comparison to GAC for a commercial industrial development did not highlight any contaminants of concern. No individual contaminants were recorded above the relevant GAC nor were exceedances recorded where conservative worst case speciated GAC were adopted for total TPH and PAH analysis (see Figures 17 and 19).

Notwithstanding this, petroleum hydrocarbon, chemical and landfill odours were noted in several locations throughout the shallow Made Ground (<0.5 m bgl) within Phase 6 including WS3_2007,

TPA10, TP309, TP6001, TP6003 and TP6006, however most notably a black oily liquid was recorded in TP201 at 0.7 m bgl which would warrant further investigation to delineate the extent of impact.

It is also noted that minimal analysis of asbestos in soils has been undertaken within the Phase (see Figure 12).

10.4.2. Soil Results – Groundwater Risk Assessment

A relatively limited dataset of soil leachate data was available for review with testing restricted to the investigations undertaken by PBA in 2009.

When compared to current controlled waters GAC several metals (cadmium, chromium, copper, lead and vanadium), inorganics (sulphate and pH) and organics (total PAHs, anthracene, flouranthene and EPH) are identified to be in a form that that could be mobilised and are considered risk items for controlled waters. These are discussed further below.

Metals and Metalloids

Cadmium

Leachable cadmium was recorded in excess of GAC in two locations at the south eastern extent of Phase 6 within BH2009/5 at 0.0-0.4m (2.4 µg/l), TP6002 at 0.5m (0.81 µg/l) and TP6002 at 4.0m (0.82 µg/l). Given the marginal nature of the exceedances, the tendency of leachate analysis to overestimate contamination due to the aggressive nature of analysis they not considered to pose a risk to controlled waters.

Chromium

Leachable chromium was recorded in two locations TP6003 at 3.5 m (7 µg/l) and TP6004 at 0.5 m (7.4 µg/l). Given that the exceedances of the GAC are small, and that leachate analysis over-estimates the actual leachability of substances from soils due to the analytical methods used, the recorded chromium concentrations are not considered to be of concern.

Copper

Leachable copper was recorded in a single location, BH2009/1 at 0.2-0.8m (41 µg/l). Given that the exceedance of the GAC is small, and that leachate analysis over-estimates the actual leachability of substances from soils due to the analytical methods used, the recorded copper concentration is not considered to be of concern.

Lead

Leachable lead was recorded in a single location, TP6006 at 2.5m (18 µg/l), which is located under a proposed area of hardstanding and is not considered to pose a risk to controlled waters.

Vanadium

Leachable vanadium was recorded in excess of GAC in one location TP6004 at 0.5m (89 µg/l). Given that the exceedance of the GAC is small, and that leachate analysis over-estimates the actual leachability of substances from soils due to the analytical methods used, the recorded vanadium concentration is not considered to be of concern.

Inorganics

Sulphate

Sulphate was recorded in several locations throughout Phase 6 including TPA10 at 0.2-0.5 m (1,200 mg/l), TPA08 at 0.2-0.6 m (890 mg/l), BH2009/2 at 0.5 m (510 mg/l), TP6002 at 0.5 m (640 mg/l) and TP6006 at 0.4 m (890 mg/l). However, these locations are predominantly present under areas of

proposed buildings and hardstanding and are not considered to pose a significant risk to end users or the water environment. Risks to building materials from sulphate attack are discussed further in the accompanying geotechnical report.

pH

Alkaline leachate was recorded in two locations within TP6004 at 0.5 m (pH 10.667) and TP6010 at 0.5 m (pH 9.58).

Organics

PAHs

Leachable PAHs, recorded as anthracene, fluoranthene or total PAH were recorded 25 No locations within Phase 6, predominantly in the northern central and south eastern sections of the phase. The depth of leachable PAH is noted to be variable throughout the Made Ground from depths as shallow as 0.2 mbgl up to a maximum depth of 4.5 mbgl. The highest density of leachable PAH was recorded as part of trial pitting undertaken in 2009 to delineate PAH impacts to groundwater at two locations advanced as part of earlier ground investigations (WS8_2007 and BHC).

Petroleum Hydrocarbons

In addition leachable EPH, TPH and mineral oil was recorded within the Made Ground in BHB at 1.0 m (530,000 µg/l), TPK at 0.5 m (170,000 µg/l), TPA10 at 0.2 to 0.5 m (340 µg/l), TPA8 at 0.2-0.6 m (120 µg/l), BH2009/2 at 0.5 m (890 µg/l) and BH2009/7 at 1.4-1.7 m (190 µg/l). With the exception of TPA08 these concentrations do not correlate with visual/olfactory observations during site works. It is also noted that EPH analysis was limited to a single investigation only and that results may not represent the distribution across the phase as a whole.

Notwithstanding this, the risks to controlled waters from leachable organics (PAHs and EPH/TPH) requires further investigation as part of risk evaluation.

In summary the historical ground investigations have identified concentrations of leachable chromium, vanadium, pH, PAHs and petroleum hydrocarbons within areas of proposed open space and/or soft landscaping that could be mobilised and thus require further consideration as part of this risk evaluation.

10.4.3. Groundwater Results

Adopting a conservative approach as for previous phases, comparison of concentrations of determinands in groundwater has been made to Environmental Quality Standards (EQS) for freshwater and, where these are not available, to UK Drinking Water Standards (DWS).

Metals and Metalloids

Chromium

Marginally elevated concentrations of chromium were encountered within BHB (6 µg/l max), BHC (9 µg/l max), BHE (14 µg/l max), BHF (12 µg/l max), BHG2 (17 µg/l max), BH112 (13 µg/l max) and WS8_2007 (17 µg/l max). The elevated concentrations of chromium occurred in both the natural strata (River Terrace Deposits and Lambeth Group) and within the Made Ground.

Adopting a conservative approach, comparison of concentrations of chromium was applied to the GAC for chromium VI (3.4 µg/l), should the 95th percentile GAC **Error! Bookmark not defined.** for total chromium be adopted no exceedances would be recorded. On this basis the risk is considered to be low and will not be evaluated further as part of this assessment (see Figure 22).

Copper

Elevated concentrations of copper (GAC of 10 µg/l) were encountered within a well installed across the Made Ground, River Terrace Deposits and Lambeth Group within BHG1 (15 µg/l max). Further exceedances were recorded in the Lambeth Group and Chalk within BH2009/04 (20 µg/l max) and BH2009/5 (150 µg/l max) respectively. Considering the isolated, marginal nature of these exceedances the risk to controlled waters is considered to be low and further assessment is not warranted (see Figure 23).

Iron

Elevated concentrations of iron (GAC of 1,000 µg/l) were encountered within the Made Ground within WS8_2007, BH112, BHC, BH2009/4 and BH2009/7 with maximum concentrations of 38,000 µg/l, 2,700 µg/l, 23,000 µg/l, 3,900 µg/l and 6,600 µg/l respectively. Concentrations of iron are generally higher in up-gradient wells (southwest of phase) and are considered to be representative of regional trends rather than as a result of an onsite contamination source. Consequently impacts are not considered further as part of this assessment (see Figure 24).

Manganese

Groundwater samples were analysed for manganese in three ground investigations dating from 2002, 2007 and 2009 against a GAC of 30 µg/l. Elevated concentrations were recorded in several strata including within standpipes installed across the Made Ground, River Terrace Deposits and Lambeth Group in BHG1 (312 µg/l max), BHB (220 µg/l max), BHC (3,000 µg/l max), BHE (690 µg/l max) and WS8_2007 (5,000 µg/l max) (see Figure 26).

Furthermore, elevated concentrations were recorded solely in the River Terrace Deposits within BH2009/2 (240 µg/l max) and BH2009/6 (730 µg/l max) within in the Lambeth Group in BH112 (610 µg/l max), BH2009/4 (390 µg/l max) and BH2009/7 (710 µg/l max) and within the Chalk in BH2009/1 (260 µg/l max).

Elevated concentrations of manganese have also been identified regionally following a review of historic EA data and are not considered to be representative on an onsite source of contamination. As such risks are not considered further as part of this assessment.

Mercury

Elevated concentrations of mercury were recorded within the Lambeth Group within BH2009/4 and BH2009/7 within an order of magnitude of the GAC (0.05 µg/l) at 0.60 µg/l maximum and 0.80 µg/l maximum respectively. Considering the isolated, marginal nature of these exceedances the risk to controlled waters is low and further assessment is not warranted (see Figure 27).

Nickel

Marginal exceedances of the nickel GAC (20 µg/l) were recorded in two locations within Phase 6 within the Made Ground and Lambeth Group at BHC (25 µg/l max) and WS8_2007 (43 µg/l max). Due to the isolated, marginal nature of these exceedances they are only considered to represent a low level of risk to the water environment and further assessment is not warranted (see Figure 28).

Inorganics

Nitrates

Elevated concentrations of nitrate were encountered within BHG1 (300 µg/l) within a standpipe installed across the Made Ground, River Terrace Deposits and Lambeth Group (see Figure 29).

Ammonia

Elevated concentrations of ammonia were encountered in several locations and strata at the site, namely:

- i. Within standpipes installed across Made Ground, River Terrace Deposits and Lambeth Group within BHC (18,000 µg/l max), BHE (2,000 µg/l max) and WS8_2007 (24,000 µg/l max);
- ii. Within the River Terrace Deposits within BH2009/2 (900 µg/l max) and BH2009/6 (3,200 µg/l max);
- iii. Within the Lambeth Group within BH112 (1,000 µg/l max) and BH2009/7 (1,400 µg/l max); and
- iv. Within the Chalk within BH2009/1 (1,000 µg/l max).

The generally high concentrations of ammonia are recorded within all strata underlying the site at various spatial locations; as such, impacts are likely to be diffuse and may be reflective of nitrates from fertilizers within the catchment area. a. Notwithstanding this the risk from ammonia warrant further assessment but due to the diffuse nature of contamination is unlikely to reap any benefit from remedial intervention (see Figure 20).

Organics

Phenol

Marginally elevated concentrations of phenol above GAC (7.7 µg/l) were only recorded in a single location in the centre of the phase within BHB (8.3 µg/l) in the Made Ground. Considering the marginal nature of the exceedance and its presence being restricted to perched water in the Made Ground the risk to controlled waters from phenol is likely to be low and no further assessment is warranted (see Figure 34).

PTPHs

Concentrations of petroleum hydrocarbons in groundwater were relatively low across the majority of the phase with exceedances of GAC (10 µg/l) only recorded in four locations within the Made Ground within BHG1 (2,000 µg/l max), BHC (470 µg/l max), BHE (100 µg/l max) and WS8_2007 (33 µg/l max). These locations do not correlate with those where leachable EPH/TPH/mineral oil was recorded in soil which suggests that minimal leaching is occurring onsite and that the TPH impacts in soil are not being realised in groundwater in the River Terrace Deposits, Lambeth Group or Chalk. As impacts of hydrocarbons on groundwater are constrained to the Made Ground the risks to controlled waters are considered to be low (see Figures 32 and 33).

PAHs

Elevated concentrations of PAHs were widespread within groundwater in Made Ground across the phase with total PAH, flouranthene, benzo(a)pyrene and anthracene recording exceedances in several locations including BHB, BHC and BHE and BHG1. Elevated concentrations of PAHs were also recorded within the River Terrace Deposits at the up-gradient end of the phase within BH2009/6 and within the Lambeth Group with BH2009/7 and BH112. While above adopted GACs the concentrations recorded in these strata were generally low and below 1 µg/l i.e. within an order of magnitude for the total PAH GAC of 0.1 µg/l (see Figure 32).

The exception to this was within WS8_2007 which lies just outside the southeast boundary of Phase 6 where total PAH concentrations were recorded between 2.9 µg/l and 5.0 µg/l which are elevated to the extent that warrants further investigation and remedial intervention. It is noted that remediation in this area was recommended by PBA but has not been undertaken to date.

Bacteriological

Groundwater within the Made Ground, River Terrace Deposits, Lambeth Group and Chalk at WS8_2007, BHC, BH112, BH2009/1, BH2009/4 and BH2009/5 has been found to be impacted by bacteria of various types (including E. Coli and Coliforms) with the highest concentrations recorded in Chalk. The presence of bacteria was recorded in 2007 and 2009 in both groundwater and surface water suggesting that there was a continuing replenishing source of bacteria, the source of which is not known, neither is whether this continues to the current day. Potential sources of bacteria could include the current and former sewage treatment works in the area or the materials deposited in landfills. However it is

understood that a bentonite cut off wall is in place around the sewage beds and that they are located hydraulically down gradient of the site, rendering that source unlikely. Other potential sources could be the cess pits at Pingmead Industrial Estate, further unknown cesspits, or nearby migration in groundwater from nearby landfills (see Figure 37).

Surface Water

Within the Trout Lakes elevated concentrations of ammoniacal nitrogen were recorded on two occasions in 2005 up to a maximum of 900 µg/l. These are comparable to concentrations recorded within the groundwater within the River Terrace Deposits (see Figure 38). No other contaminants were recorded to be elevated within the Trout Lakes.

Ground Gas

Potential sources of ground gas at the Phase 6 area include:

- i. Natural sources arising from the decay of organic material in Alluvium, typically around 0.5 m thick;
- ii. Natural sources arising from the dissolution of deep Chalk;
- iii. Decay of anthropogenic material and plant material in landfilled Made Ground which have been identified at thicknesses of up to 4.7 m;
- iv. Degradation of shallow hydrocarbon contamination in soil and/or groundwater; and
- v. The historic landfills within and immediately to the north of Phase 6.

Within Phase 6 and the immediate surrounding proposed open space to the northeast a total of seven wells have been installed and monitored for ground gas (BHG1, BHA, BHB, BHC, BHE, BH112 and WS7_2007) with a further three wells monitored to the southeast of the phase (BHF, WS6_2007 and WS8_2007) and one to the northeast (BHG2).

Generally these wells have been monitored on up to 14 occasions under atmospheric pressure conditions varying between 998 mb and 1027 mb. On the majority of monitoring visits the response zones within monitoring wells BHG1, BHA, BHB, BHC, BHE, BHF, WS6_2007 WS7_2007 were partially saturated allowing the monitoring of the unsaturated Made Ground in BHG1, BHA, BHB, BHC, BHE, WS7_2007 and WS8_2007 and the unsaturated Made Ground and Alluvium and River Terrace Deposits in BHG2 and WS6_2007. Where response zones were fully saturated / flooded the results recorded have been discounted from this assessment e.g. BH112.

To date the highest methane concentration was recorded at 54 %v/v within WS7_2007 on 18 July 2007. Concentrations in excess of 1 %v/v methane were recorded on several occasions within BHC, BHE, BHG1, WS6_2007, and WS8_2007. Of these, five locations recorded a concentration of more than 10% on at least one occasion. Organic material is identified in the exploratory hole logs for BHA, BHB, BHC, WS7_2007 and WS7_2008 as black staining, bitumen and wood within Made Ground that is up to 4.7 m thick.

The highest carbon dioxide concentration was recorded at 20 %v/v within BHC recorded on 4 July 2007. Concentrations in excess of 5 %v/v were recorded in five other wells (BHE, BHG1, BHG2, WS6_2007 and WS7_2007) on at least three occasions.

Within unsaturated response zones gas flow rates were generally recorded below 1.0 l/hr, however, the highest recorded steady state flow rate was within BHC on 4 July 2007 at 2.1 l/hr. On this occasion a peak flow rate was record in excess of 30 l/hr.

A summary of ground gas results for Phase 6 and the open space to the northeast and southeast is contained in Table 30 below (see Figure 40).

Table 30 Phase 6 – Peak Ground Gas Results

ID	Response Zone (m bgl)	Water Level (m bgl)	Peak Carbon Dioxide (CO ₂) concentration (% v/v)	Peak Methane (CH ₄) Concentration (% v/v)	Gas Flow Rate (l/hr)
BHA	1.00 – 5.50	1.1	0.0	0.0	0.2
BHB	1.00 – 5.50	1.18- 1.25	0.4	0.0	0.3
BHC	1.00 – 4.50	1.47	20	26	2.1
BHE	1.00 - 4.00	1.30 – 1.70	5.5	32.5	0.6
BHF	1.00 – 3.60	1.33	9.8	0.7	0.2
BHG1	1.00 - 5.10	1.78 – 1.81	7.1	4.7	0.9
BHG2	1.00 – 5.00	2.27 – 2.68	11.8	0.0	0.0
BH112	8.50 - 9.50	2.17 – 2.82	0.2	0.0	0.1
WS6_2007	1.00 – 2.00	1.43 – 1.57	19.0	1.7	0.7
WS7_2007	2.00- 2.80	1.51 – 1.60	16.0	54.0	0.4
WS8_2007	1.00 – 4.00	1.35 – 1.72	3.8	9.6	0.3

Using the worst case unsaturated zone flow rate of 2.1 l/l a GSV has been calculated for Phase 6 as 1.13 for methane and 0.42 for carbon dioxide which would result in a Characteristic Situation classification of CS3 under CIRIA C665. The CS3 classification is regarded as typical for an old landfill and would be considered appropriate for setting of Phase 6 upon a former waste transfer station.

10.6 Uncertainties and Gaps in the Information

There has been limited asbestos testing undertaken from shallow soils in Phase 6, which given the historical usage of the site could be a key contaminant of concern. Risks to health, particularly during the construction phase, may be present. Further testing for asbestos within the upper Made Ground is recommended during additional investigations.

Previous soil testing was not always carried out for fully speciated organic compounds (PAHs and TPHs) which renders assessment to current standards difficult. Consequently the methodology adopted as part with this assessment is likely to be overly conservative as the worst case conditions have been considered.

Due to PAH impacts to controlled waters at WS7_2007 PBA recommended remediation works be undertaken. To date there is no information available relating to whether this work was undertaken.

In relation to groundwater risks the spatial distribution of monitoring wells at the hydraulically down-gradient end of the area (Phase 6 and 7) is relatively limited, particularly within the Lambeth Group and Chalk. While significant contamination impacts have not been identified in these strata it is difficult to comprehensively assess whether the contaminants that are present are likely to impact offsite receptors.

The source of bacteria identified in groundwater within the Made Ground, River Terrace Deposits, Lambeth Group and Chalk is unknown. The dewatering of the north western Trout Lake has the potential to alter the distribution of mobile contaminants in groundwater and surface water as well as impact the ground gas regime with Phase 6. To date only minimal assessment has been undertaken and further understanding of the likely impacts is required. Furthermore in relation to the Trout Lake, there is currently no data on the quality of sediments/soils at the base of the Lake which could pose a risk of creating pathways for contaminant migration during piling. It would be prudent to undertake sampling ahead of foundation works.

The level of gas monitoring undertaken to date is not sufficient to comply with current British Standards and UK specific guidance. In addition the spatial distribution of gas monitoring wells is fairly limited within the phase and, given the thickness of Made Ground and gas concentrations encountered in historical monitoring by PBA this would warrant further investigation/monitoring and assessment. Phase 6 also incorporates the dewatering and filling of the north western Trout Lake. The temporary drawdown of the groundwater levels may result in changes in the ground gas regime that could be sustained over the long term and monitoring throughout the duration of dewatering is recommended. Furthermore the proposed filling and land raise at the site could bring about long term changes in the ground gas regime due to additional loading/compression of the existing strata. Wells installed during the additional ground investigations within the phase should be sited and designed to allow for extension vertically should be drilled outside of garden areas post earthworks.

10.7 Risk Evaluation and Conceptual Model

The low sensitivity, commercial nature of the proposed development involving raising ground levels by on average approximately 1 m largely inhibits contamination pathways to human health in the operational phase, however impacts could be realised during the construction for construction workers and users of adjacent site including earlier developed phases at the site.

The Made Ground within Phase 6 and Phase 1C West has been shown to contain potential controlled waters hazards including chromium, vanadium, PAHs and petroleum hydrocarbons which are present in a mobile form (there is less evidence of impact in Phase 7). However, based on the data collected by PBA, there is limited evidence to suggest that these are having a significant impact on the underlying groundwater bodies and there is a general reduction in contaminant concentrations with depth across the perched water/groundwater in the Made Ground and River Terrace Deposits and deeper groundwater within the Lambeth Group and Chalk. This suggests that, to a certain extent, the Lambeth Group is limiting the downward migration of contamination under the current site conditions.

While elevated concentrations of iron, manganese and ammonia have been identified in the majority of strata historical regional groundwater data suggests these concentrations are reflective of regional trends rather than an onsite contamination source. Remediation of the contaminants is likely to have limited benefit at the site.

PAHs are present in both in soil leachate and groundwater, but generally at concentrations marginally above GAC where impacts to controlled waters are considered to be low and further assessment is not warranted. However, within WS8_2007 elevated PAHs up to 5 µg/l were identified which also correspond to the highest concentrations of ammoniacal nitrogen within the phase at 24,000 µg/l. Consequently we would concur with the PBA conclusion that further assessment and remedial intervention should be undertaken at this location, specifically for these contaminants.

Concentrations of petroleum hydrocarbons in groundwater were relatively low across the majority of the phase with exceedances constrained to the Made Ground in four locations BHG1 (2,000 µg/l max), BHC (470 µg/l max), BHE (100 µg/l max) and WS8_2007 (33 µg/l max). Given the magnitude of these concentrations further assessment is warranted, however it is noted that no impact was recorded in the deeper groundwater bodies in the River Terrace Deposits, Lambeth Group or Chalk.

Bacteria have been identified in groundwater within the Made Ground, River Terrace Deposits, Lambeth Group and Chalk within WS8_2007, BHC, BH112, BH2009/1, BH2009/4 and BH2009/5. At present the historical source of this bacteria is unknown, nor is it known whether this source is replenished to the current day.

The qualitative hazard assessment identifying potential pollutant linkages has been undertaken below using the source-pathway-receptor framework detailed in Appendix 1. An assessment of the potential significance of each linkage has been made by consideration of the likely magnitude and mobility of the source, the sensitivity of the receptor and nature of the migration/exposure pathways.

Table 31 Phase 6, Phase 7 and Phase 1C West Conceptual Site Model

Potential Source	Potential Contaminant (s)	Pathway	Potential Receptor	Probability of Risk Being Realised*	Consequence of Risk Being Realised*	Risk Classification*
Made Ground	No human health contaminants of concern have been identified in respect to a commercial / industrial end use. However concentrations that could have an acute impact have been identified along with visual and olfactory evidence of hydrocarbon contamination	Dermal contact	Construction workers	Likely	Mild	Moderate/low
		Inhalation of soil dust	Construction workers	Likely	Mild	Moderate/low
			Adjacent site and phase users	Low likelihood	Mild	Low
		Ingestion of soil	Construction workers	Low likelihood	Mild	Low
	Asbestos in soils	Inhalation of released fibres	Adjacent site and phase users	Unlikely	Severe	Moderate/Low
			Construction workers	Low Likelihood	Severe	Moderate
	Leachable contaminants in Made Ground in several locations including chromium, Vanadium, pH, PAHs and TPH/EPH	Vertical and lateral migration via permeable strata	Surface water – Trout Lakes	Unlikely	Medium	Low
			Secondary Aquifers	Low likelihood	Medium	Moderate/Low
	Petroleum hydrocarbons	Permeation of buried water service pipes	Future site users	Unlikely (providing pipes are laid in clean cover material to be placed over the Made Ground)	Medium	Low
Perched water in vicinity of WS8_2007	PAHs in soil and/or groundwater	Migration in groundwater, including vertical and lateral pathway creation via foundation works	Surface water – Trout Lakes	Low likelihood	Medium	Moderate/Low
			Secondary Aquifers	Likely	Medium	Moderate
			Principal Aquifer	Low likelihood	Medium	Moderate/Low
		Vapour inhalation	Construction workers	Low likelihood	Mild	Low
		Vapour inhalation	Future site users	Low likelihood	Medium	Moderate/low
Made Ground in BHG1, BHC, BHE and WS8_2007	TPH in soil and/or groundwater (including potential free phase)	Vertical and lateral migration via permeable strata and foundations	Surface water – Trout Lakes	Low likelihood	Medium	Moderate/Low
			Secondary Aquifers	Likely	Medium	Moderate
			Principal Aquifer	Low	Medium	Moderate/Low
		Vapour inhalation	Construction workers	Low likelihood	Mild	Low

Potential Source	Potential Contaminant (s)	Pathway	Potential Receptor	Probability of Risk Being Realised*	Consequence of Risk Being Realised*	Risk Classification*
		Vapour inhalation	Future site users	Low likelihood	Medium	Moderate/low
Diffuse, regional groundwater contamination	Ammonia, Iron and Manganese	Vertical and lateral migration via permeable strata	Surface water – Trout Lakes	Low likelihood	Mild	Low
			Secondary Aquifers	Low likelihood	Mild	Low
			Principal Aquifer	Low likelihood	Mild (not within a groundwater source protection zone)	Low
Bacteriological	Bacteria/pathogens	Dermal contact	Construction workers	Unlikely	Mild	Very low
		Inhalation of soil dust	Construction workers	Unlikely	Mild	Very low
			Adjacent site and phase users	Unlikely	Mild	Very low
		Ingestion of soil and water	Construction workers	Low likelihood	Mild	Low
		Leaching to groundwater and migration in groundwater	Surface water – Trout Lakes	Low likelihood	Mild	Low
			Secondary Aquifers	Low likelihood	Mild	Low
			Principal Aquifer	Low likelihood	Mild (not within a groundwater source protection zone)	Low
Made Ground, Alluvium and Chalk	Ground gases - carbon dioxide and methane	Migration of gases and build up in confined spaces	Future site users	Likely	Medium	Moderate
			Construction workers	Likely	Medium	Moderate
			Building materials / structures	Likely	Medium	Moderate
			Adjacent site and phase users	Unlikely	Medium	Low
		Lateral gas migration caused by development design	Adjacent building structures	Unlikely	Medium	Low

Note All risks assume no mitigation in place - for definition of terms see Appendix 1

10.8 Conclusions

The geo-environmental setting within Phase 6, Phase 1C West, Phase 7 has been manipulated by historic activities with evidence of localised ground workings and more substantial mineral extraction to form the Trout Lakes. The Phase has also been utilised as a waste transfer and treatment facility and there is evidence that these activities have resulted in moderate to low levels of contamination within the phase. As part of the proposed commercial development the site levels are proposed to be raised by approximately 1 m with up to 5 m of filling anticipated within the north western Trout Lake.

A number of potential pollutant linkages are present at Phase 6, Phase 1C West and Phase 7, which will require further investigation and risk assessment to determine the requirement for and extent of remedial measures. These include the following risks:

- i. Asbestos in Made Ground, for which there has been limited testing;
- ii. Bacteriological contamination within groundwater across the phase;
- iii. PAH impacts in soil leachate and perched water within the Made Ground at WS8_2007;
- iv. Petroleum hydrocarbon impacts within the Made Ground in BHG1, BHC, BHE and WS8_2007 which have the potential to impact controlled water and water supply pipes;
- v. The extent of hydrocarbon/chemical odours identified in TP201, WS2_2007, WS3_2007, TPA10 and TP309; and
- vi. Ground gases which may build up in confined spaces causing a risk to end users and future building structures

10.9 Recommendations and Implications for Design, Construction and Project Planning

The low sensitivity, commercial nature of the proposed development involving raising ground levels by on average approximately 1m largely inhibits contamination pathways to human health in the operational phase, however impacts could be realised during the construction for construction workers and users of adjacent sites including earlier developed phases at the site. Further investigation into the asbestos content of the shallow Made Ground is required. Notwithstanding this it is considered that impacts to these receptors would be largely mitigated through the use of appropriate PPE and on-site health, safety and environmental procedures. In particular, and depending upon the findings of supplementary investigations, specific controls for the release of soil dust / asbestos fibres during site works may be required in order to protect ground workers and users of nearby land.

A review of available ground gas data for the site indicates that ground gas protection measures conforming to a Characteristic Situation of 3 are required, however the available information is dated and the spatial distribution of monitoring wells is relatively limited. As such the drilling of additional wells is required and additional monitoring is recommended which should utilise continuous monitoring equipment so that changes with atmospheric pressure and groundwater level can be determined. Given that site levels are proposed to be raised, gas monitoring would be required to continue following placement of material to raise ground levels. This is necessary to ascertain whether lateral gas migration has been introduced as a result of the development scheme.

In addition further investigation of the hydrocarbon/chemical odours identified in TP201, WS2_2007, WS3_2007, TPA10 and TP309 is required to determine the extent of vapour risks, this could through an additional trial pitting exercise.

Impacts to controlled water receptors have been identified to be more significant and could be mobilised during groundworks and foundations works at the site. As such any foundations will need to be subject to a Foundation Works Risk Assessment for approval by the Environment Agency ahead of works.

Elevated concentrations of ammonia iron and manganese have been identified in groundwater and surface water, and through comparison with regional data are considered to represent wider trends than being reflective of a source on on-site contamination. Consequently, limited benefit would be achieved through remedial action. This approach should be confirmed with the Environment Agency.

Groundwater and surface water have also historically been shown to be impacted by bacteria (E.Coli and Coliforms); however it is not certain whether impacts are continuing to the current day through a replenishing source as the reviewed data dates from 2005 to 2007. The source of these bacteria was also not proven by PBA and further investigation and monitoring is recommended.

While leachable contaminants have been identified in the soils within the Phase, the potential for the infiltration of meteoric waters, and in turn on-site leaching will be minimised as the development will be predominantly be covered by hardstanding. Exceptions to this where further assessment through DQRA and/or remediation is required are highlighted below.

- i. Localised PAH and petroleum hydrocarbon contamination has been identified to the southeast of Phase 6 in WS7_2008. Remediation was previously recommended by PBA and it is unknown whether this has been undertaken. We would agree with the PBA conclusion and recommend that a remediation strategy for this works be prepared (if not completed by PBA).
- ii. Further localised petroleum hydrocarbon contamination was encountered in groundwater in several wells including BHG1, BHC and BHE up to 2,000 µg/l and further investigation of these areas is recommended to define the requirement for and extent of any remediation.

The presence of organic contamination within the soils within Phase 6 is also likely to preclude the use of PE water pipes and consultations with the local water supplier are recommended to determine the appropriate specification of pipe materials. Alternatively a series clean services corridors could be created at the site to mitigate risks.

There is relatively limited design information available for the proposed dewatering and filling of the north western Trout Lake and the associated impacts of this on contamination and the groundwater and gas regimes. If the lakes are dewatered, the dewatering activities will likely require environmental permitting. Further assessment of water quality will be necessary, and a water features survey may be required. Further investigation and assessment is required and the Environmental Agency should be consulted at the earliest opportunity.

It is recommended that these items are formalised as part of a site wide remediation strategy for submission to the Local Authority and Environment Agency.

11. TROUT LAKE DEWATERING AND FILLING

As outlined in Section 10.2 the proposed development includes the dewatering and infilling of the north western portion of the Trout Lakes which will involve raising levels from approximately 35 mAOD to 40.2 mAOD (~5.2 m of fill).

The proposed dewatering/abstraction of water from the Trout Lake requires further consideration regarding the hydrogeological setting, potential impacts upon the environment, required environmental permitting and whether there will be effects upon water quality or the gas regime.

The assessment by PBA provides a useful baseline but a significant amount of time has passed since its publication in 2008. In addition an assessment of whether the lake is lined or not needs to be undertaken, and the affects relating to the drawdown of surrounding groundwater should be revisited. If the lake is not lined and is in hydraulic continuity with the River Terrace Deposits, drawdown of groundwater would be necessary in order to dewater the lake. The radius of influence and effects from nearby water features, abstractions and boundary conditions need to be further considered.

Water abstraction is likely to require an environmental permit, and an application to investigate may also be required, part of which may include a water features survey. Discharge of water to local watercourses would also require permitting. Dewatering may draw in contaminated groundwater, and

it may not be appropriate to discharge such water to local watercourses. The local watercourses proposed to be used for discharge of abstracted water would also need to be assessed to determine whether they will be capable of taking the water flow required without causing localised flooding or damage to the banks of these watercourses.

In addition drawing down the water table may alter the ground gas regime, and could increase gas generation.

12. OVERALL CONCLUSIONS AND RECOMMENDATIONS

The site at Green Park Village has a history of potentially contaminative land-uses, particularly in the central and western sections of the site which include various industrial land uses at the Pingemead Industrial Estate and gravel extraction, landfilling and a historic waste transfer station in Phase 6. Other areas of the site have been largely open land associated with Smallmead Common. The immediately surrounding land uses include landfills and sewage treatment works which may also have affected the geoenvironmental setting of the site.

The proposed earthworks and development at the site, together with its setting in an area of sensitive groundwater, proximity to the River Kennet and associated tributaries and having the Trout Lakes in the centre of the site, renders the site vulnerable to contamination.

In order to facilitate the development a significant earthworks programme is proposed to be undertaken under an environmental permit to bring the site to minimum level of +40.2 mOD for flood alleviation purposes. This generally involves filling the site with between 1 m and 3 m of fill compliant with the specification for earthworks. This filling operation would effectively provide a clean cap mitigating human health impacts from direct soil contact and ingestion/inhalation. However, the historical investigations, undertaken predominantly by PBA, have identified a number of potential pollutant linkages from ground gas and to controlled waters which require further investigation and assessment, and/or remediation.

Table 32 provides a summary of the required additional investigation and assessment, and anticipated required remediation for each of the phases. Reference should be made to the full details provided in Sections 5 to 10.

We would recommend that this report be submitted to both the Environment Agency and Reading Borough Council Environmental Health for comment and approval.

Table 32 Summary Conclusions and Recommendations

Conclusion / Recommendation	Phase 1A East	Phase 1A West	Phase 1B	Phase 1C	Phase 2A	Phase 2B	Phase 2C	Phase 3	Phase 4	Phase 5	Phase 6	Phase 7
Further intrusive site investigation required		X	X	X	X	X	X	X	X	X	X	X
Asbestos risk – further onsite testing and assessment required and advice from asbestos specialist recommended		X	X	X	X	X	X	X	X	X	X	X
Additional remediation (e.g. removal of hotspots or free product) ¹		X*	X*	X*	X*	X*	X*	X*		X*	X*	
Additional groundwater monitoring to include monitoring for free product and vapours		X	X	X	X	X	X	X	X	X	X	
Additional ground gas monitoring (to include vapour and possibly continuous monitoring)		X	X		X	X	X	X	X	X	X	
Additional ground gas monitoring following land raise		X	X		X	X	X	X	X	X	X	

Conclusion / Recommendation	Phase 1A East	Phase 1A West	Phase 1B	Phase 1C	Phase 2A	Phase 2B	Phase 2C	Phase 3	Phase 4	Phase 5	Phase 6	Phase 7
Gas protection measures anticipated to be required (depending on results of further monitoring)		X*	X*		X*	X*	X*		X*	X	X*	
Further, more detailed, risk assessment required (to assess free product and or risks to the water environment)		X*	X*	X*	X*	X*	X*			X*	X*	
Further assessment of hydrogeological and hydraulic regime for dewatering of the Trout Lake											X	
Foundation Works Risk Assessment required	X	X	X		X	X	X	X	X	X	X	
Further assessment of lake dewatering and filling proposals											X	

* denotes conclusions and recommendations dependent upon the results of additional ground investigation

¹ remediation in addition to capping to be installed as part of the earthworks at the site

The proposed dewatering/abstraction of water from the Trout Lake requires further consideration regarding the hydrogeological setting, potential impacts upon the environment, required environmental permitting and whether there will be effects upon water quality or the gas regime.

Following the works outlined above it is recommended that a remediation strategy be prepared to address the identified risks at the site in order to bring the site into a condition that is deemed suitable for the proposed end use. Depending on the nature and phasing of development staggered remedial and verification works may be the preferable approach. Note that a Remediation Strategy would be needed to fulfil the requirements of planning condition 42.

Where site won materials are sought for re-use it is recommended that a Materials Management Plan (MMP) in accordance with the provisions of the CL:AIRE document "The Definition of Waste: Development Code of Practice" Version 2 March, 2011 is prepared. This approach will reduce the requirement for materials to be disposed of offsite as waste where an excess is present while maintaining a suitable for use approach and enable the client to achieve the desired cut/fill balance while minimising the need for import under Environmental Permit.

Throughout earthworks and construction works it is recommended that a part-time environmental watching brief is undertaken by Ramboll to verify the implementation of the additional works and required remedial works etc. and to provide guidance in the event that unexpected or gross contamination is encountered.

Following groundworks and construction at the site (or individual development phase), a verification report(s) in accordance with applicable UK guidance and legislation should be prepared to fulfil the requirements of planning condition 44. The report should document the successful completion of development and will include a detailed audit trail to ensure that the implementation of any required remedial measures was in accordance with the Remediation Strategy.

FIGURES

Figure 1 – Site Location Plan

Figure 2 – Phase Plan

Figure 3 – Site Feature Plan

Figure 4 – Historic Ground Investigation Plan

Figure 5 - Historic Ground Investigation Plan – Phase 1

Figure 6 - Historic Ground Investigation Plan – Phase 1C East and Phase 2

Figure 7 - Historic Ground Investigation Plan – Phase 3

Figure 8 - Historic Ground Investigation Plan – Phase 4

Figure 9 - Historic Ground Investigation Plan – Phase 5

Figure 10 - Historic Ground Investigation Plan – Phase 1C West and Phase 6 (North)

Figure 11 - Historic Ground Investigation Plan – Phase 1C West and Phase 6 (South)

Figure 12 – Asbestos - Soil Plan

Figure 13 – Chromium - Soil Plan

Figure 14 – Mercury – Soil Plan

Figure 15 – Lead – Soil Plan

Figure 16 – PAH (Naphthalene) – Soil Plan

Figure 17 – PAH (Total) – Soil Plan

Figure 18 – PAH (Benzo a pyrene) – Soil Plan

Figure 19 – TPH – Soils Plan

Figure 20 - Ammonia – Groundwater Plan

Figure 21 - Cadmium – Groundwater Plan

Figure 22 - Chromium – Groundwater Plan

Figure 23 - Copper – Groundwater Plan

Figure 24 - Iron – Groundwater Plan

Figure 25 - Lead – Groundwater Plan

Figure 26 - Manganese – Groundwater Plan

Figure 27 - Mercury – Groundwater Plan

Figure 28 - Nickel – Groundwater Plan

Figure 29 - Nitrate – Groundwater Plan

Figure 30 - Selenium – Groundwater Plan

Figure 31 - Zinc – Groundwater Plan

Figure 32 - PAH – Groundwater Plan

Figure 33 - TPH – Groundwater Plan

Figure 34 - Phenols – Groundwater Plan

Figure 35 – Chlorinated Solvents – Groundwater Plan

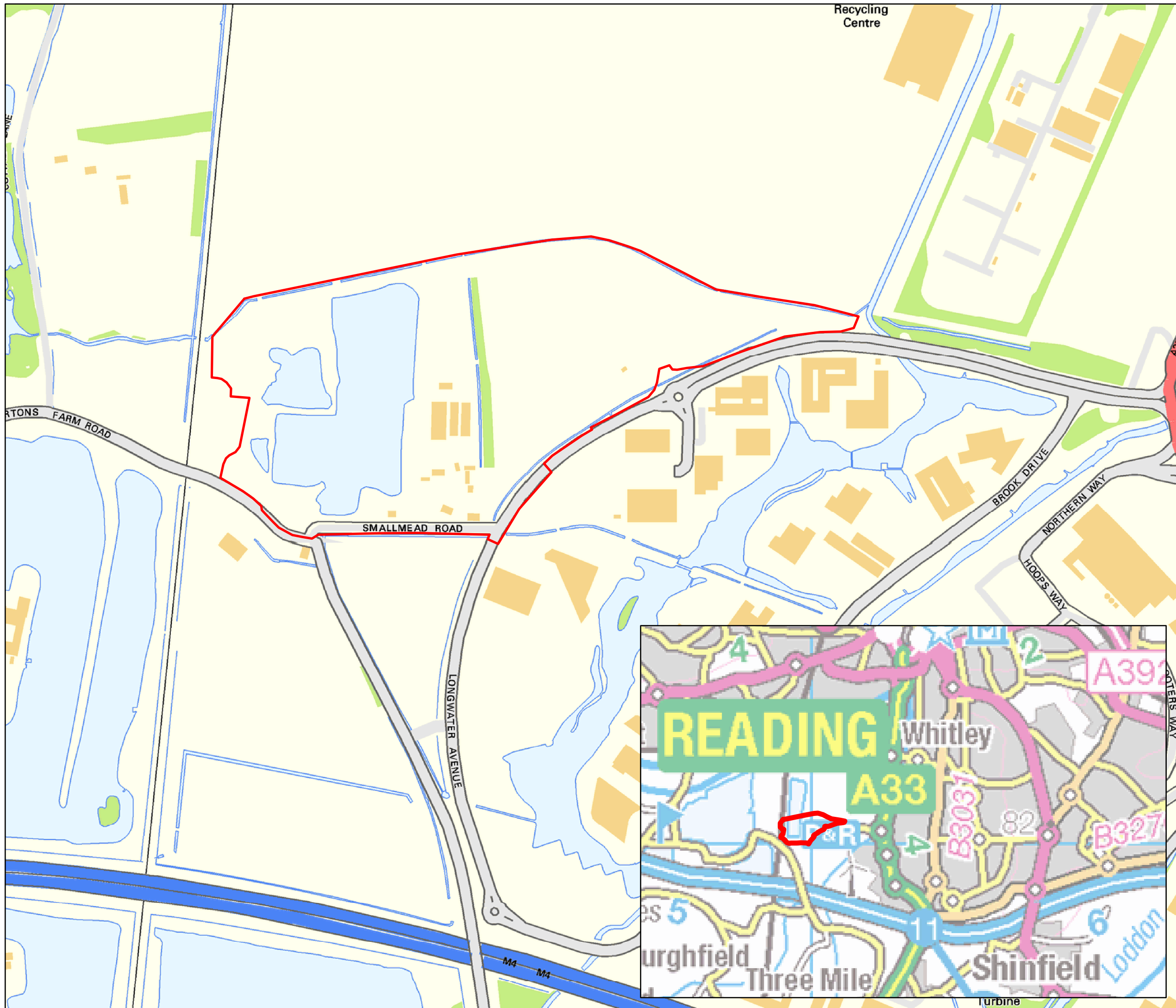
Figure 36 - Dichloromethane – Groundwater Plan

Figure 37 - Bacteria – Groundwater Plan

Figure 38 - Ammonia – Surface Water Plan

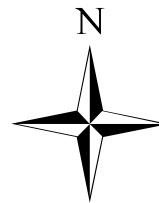
Figure 39 - PAH – Surface Water Plan

Figure 40 – Ground Gas Plan



 Site Boundary

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Client
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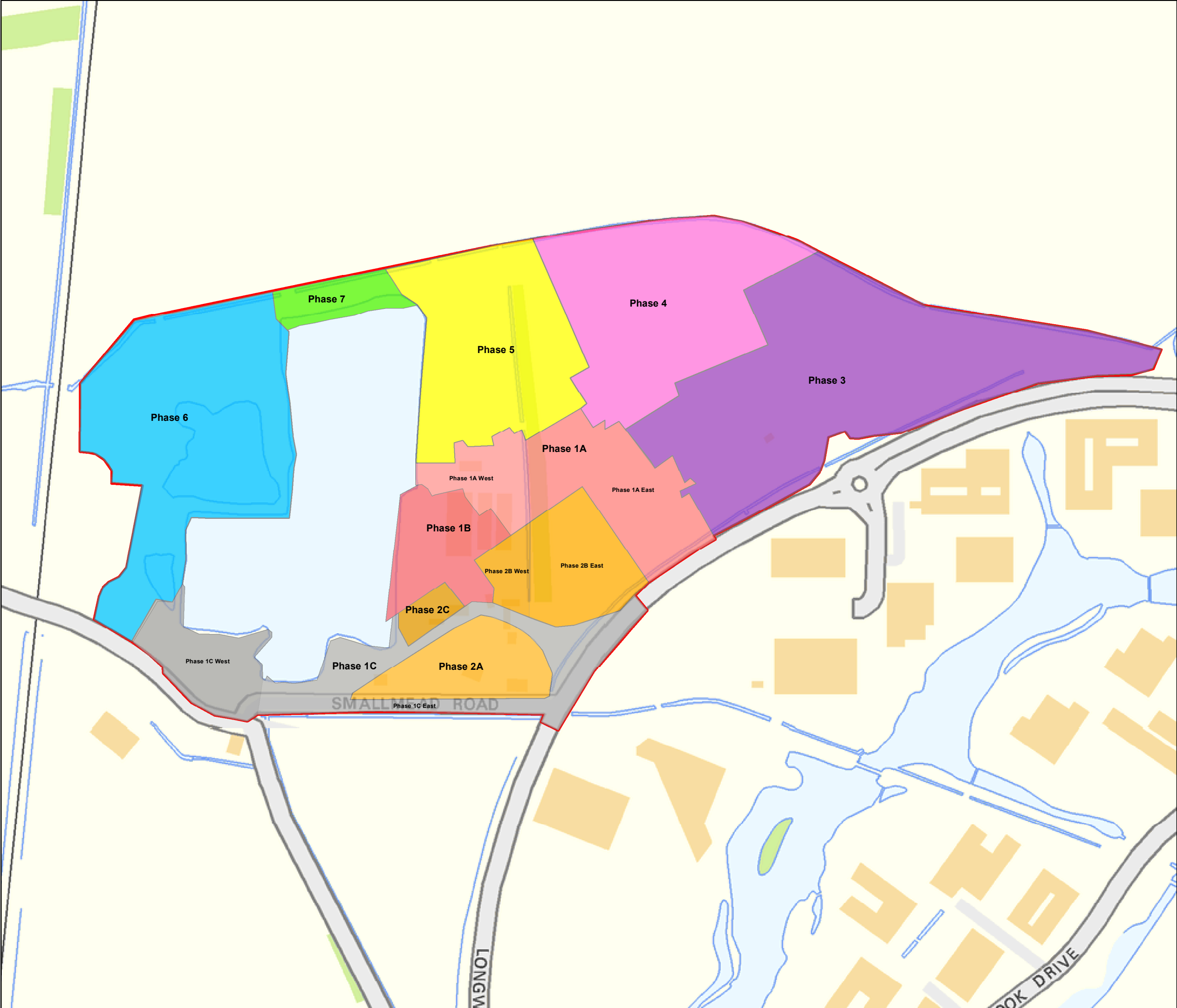
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Figure Title
Site Location Plan

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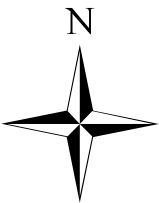
Figure No.
Figure 1
Revision
01



Site Boundary

Phase

- Phase 1A
- Phase 1B
- Phase 1C
- Phase 2A
- Phase 2B
- Phase 2C
- Phase 3
- Phase 4
- Phase 5
- Phase 6
- Phase 7



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Figure Title

Phase Plan



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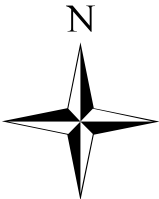
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Figure No.
Figure 2

Revision
01



- Site Features
- Site Boundary
- Historic Landfills
- Authorised Landfills



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Site Feature Plan



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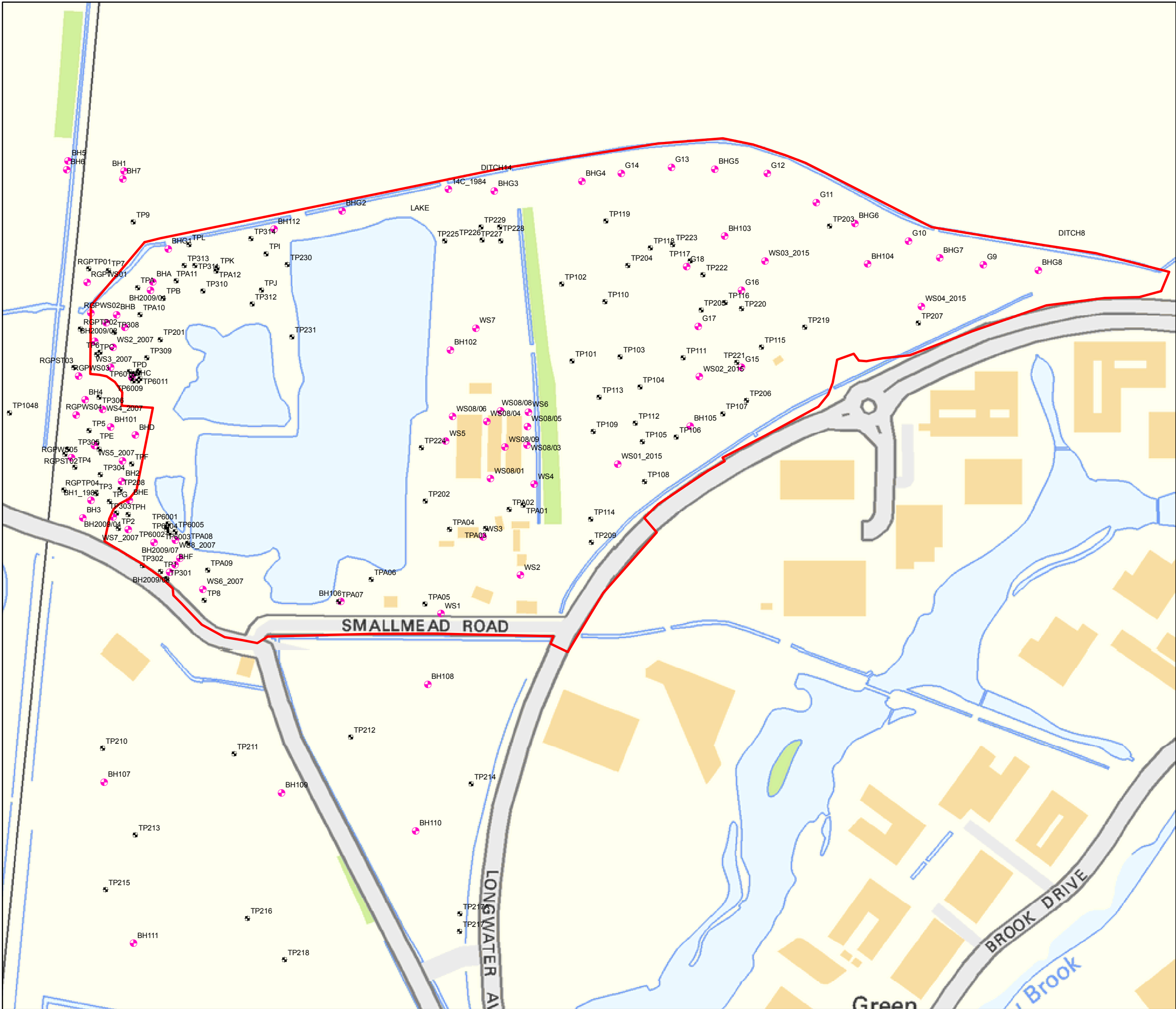
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Figure No.

Figure 3

Revision

01



- Site Boundary
- Borehole (BH)
- Trial Pit (TP)



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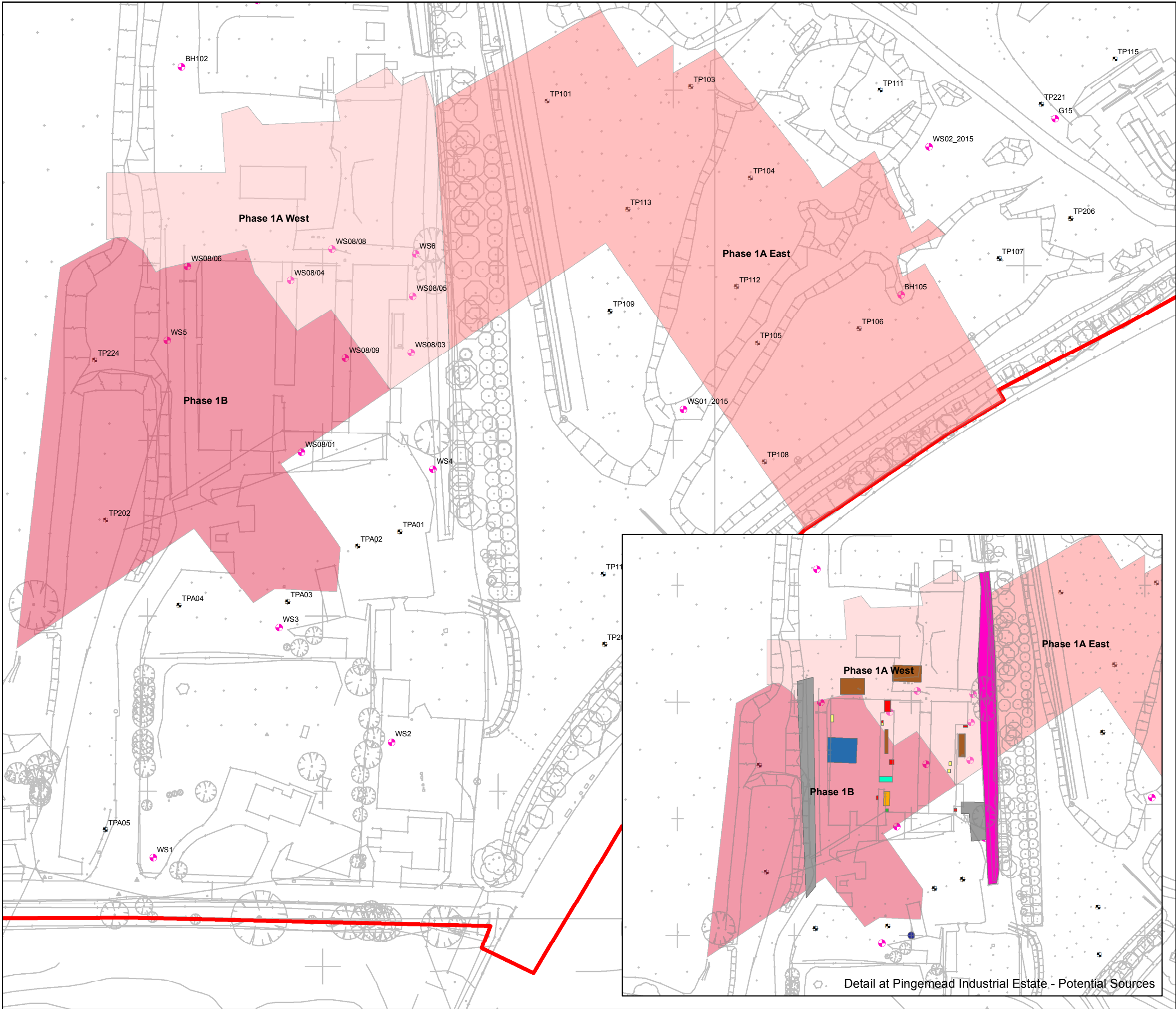
Historic Ground Investigations



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Figure No. Figure 4 Revision 01



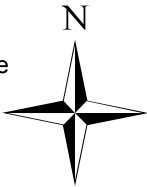
- Site Boundary
- Phase 1A East
- Phase 1A West
- Phase 1B

- Borehole (BH)
- Trial Pit (TP)

Pingemead Potential Sources

- AST Diesel / Fuel Oil
- Blocked Ditch
- Cesspit
- Chemical Storage
- Chemical Waste
- Historic Abstraction Well
- Oil Drums
- Paint Mixing and Storage
- Paint Spray Booth
- Uncontrolled Waste

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**Phase 1 Historic Ground
Investigation Plan**



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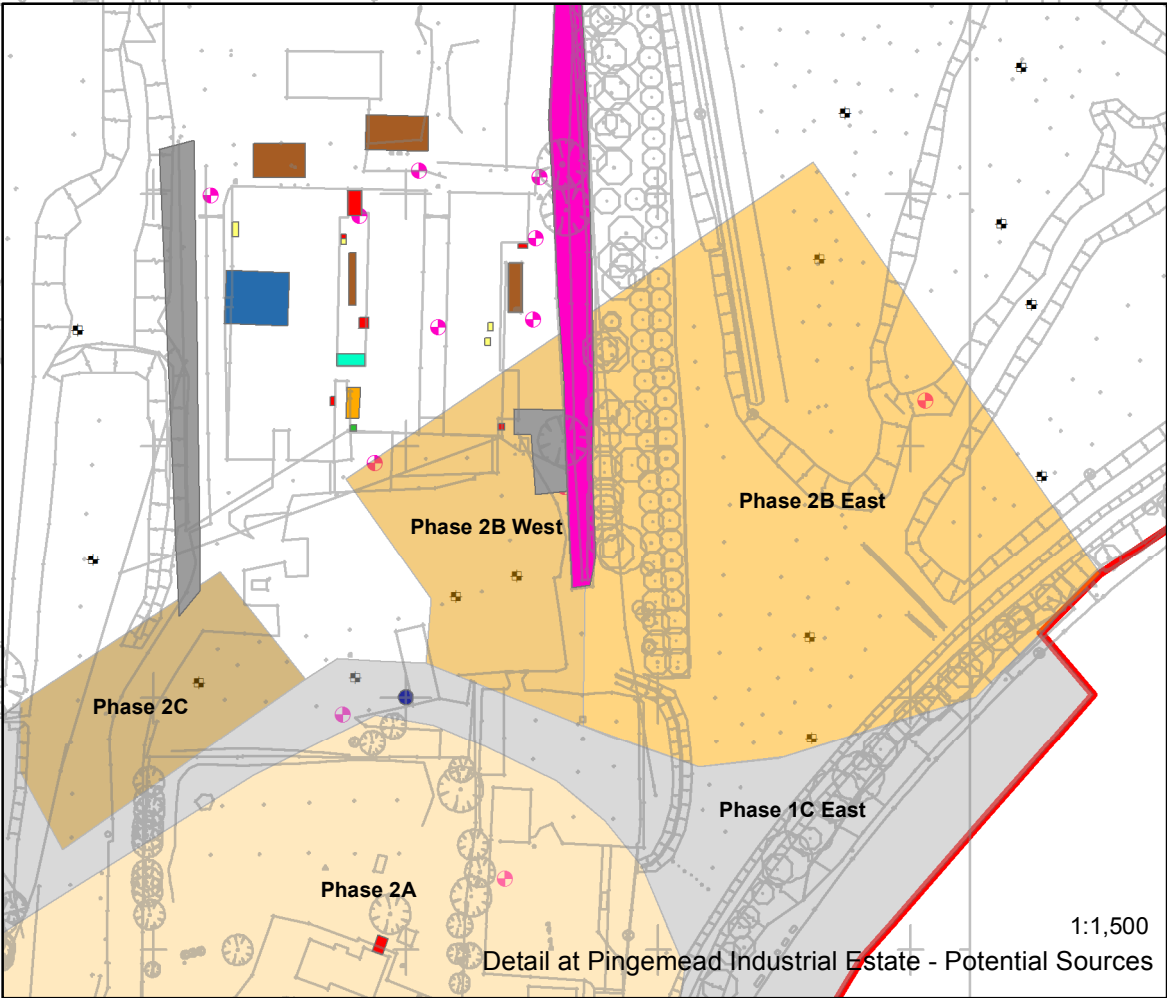
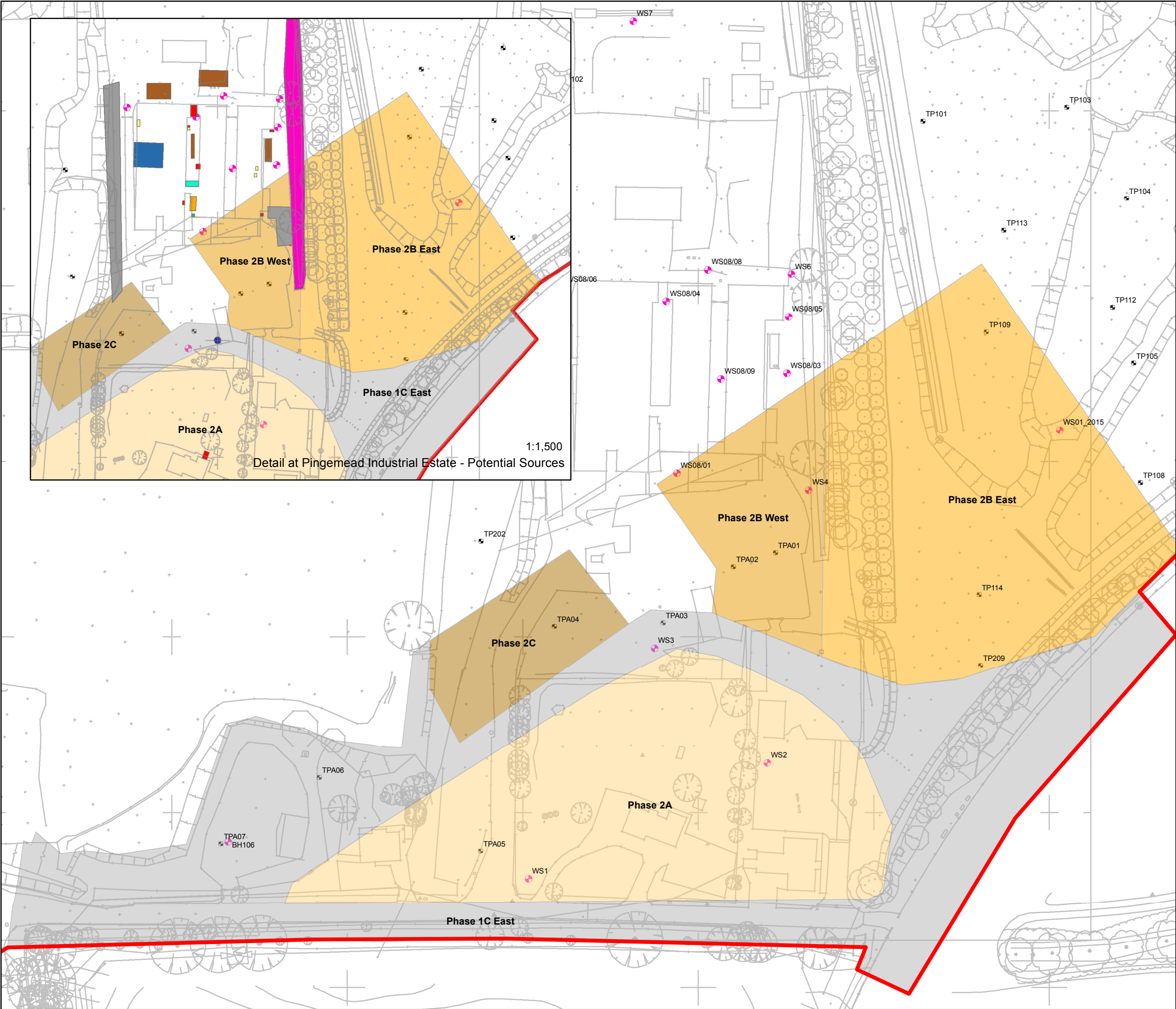
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Figure 5

Revision
01



Site Boundary

Phase 1C East

Phase 2A

Phase 2B East

Phase 2B West

Phase 2C

Borehole (BH)

Trial Pit (TP)

Pingemead Potential Sources

AST Diesel / Fuel Oil

Blocked Ditch

Cesspit

Chemical Storage

Chemical Waste

Historic Abstraction Well

Oil Drums

Paint Mixing and Storage

Paint Spray Booth

Uncontrolled Waste

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Phase 1C East and Phase 2 Historic Ground Investigation Plan

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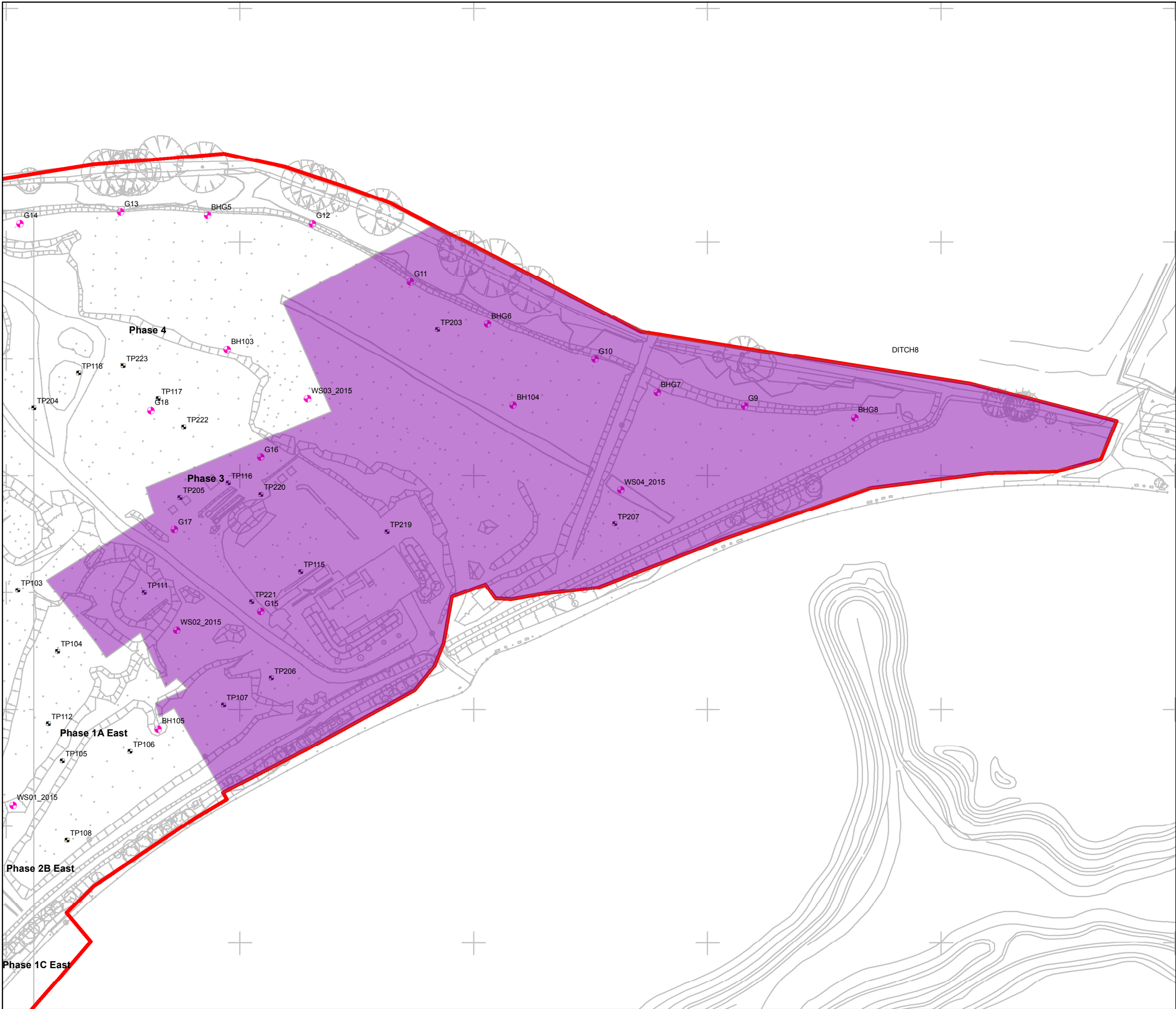
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Figure No.

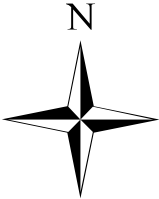
Figure 6

Revision

01



- Site Boundary
- Phase 3
- Borehole (BH)
- Trial Pit (TP)



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Figure Title

**Phase 3 Historic Ground
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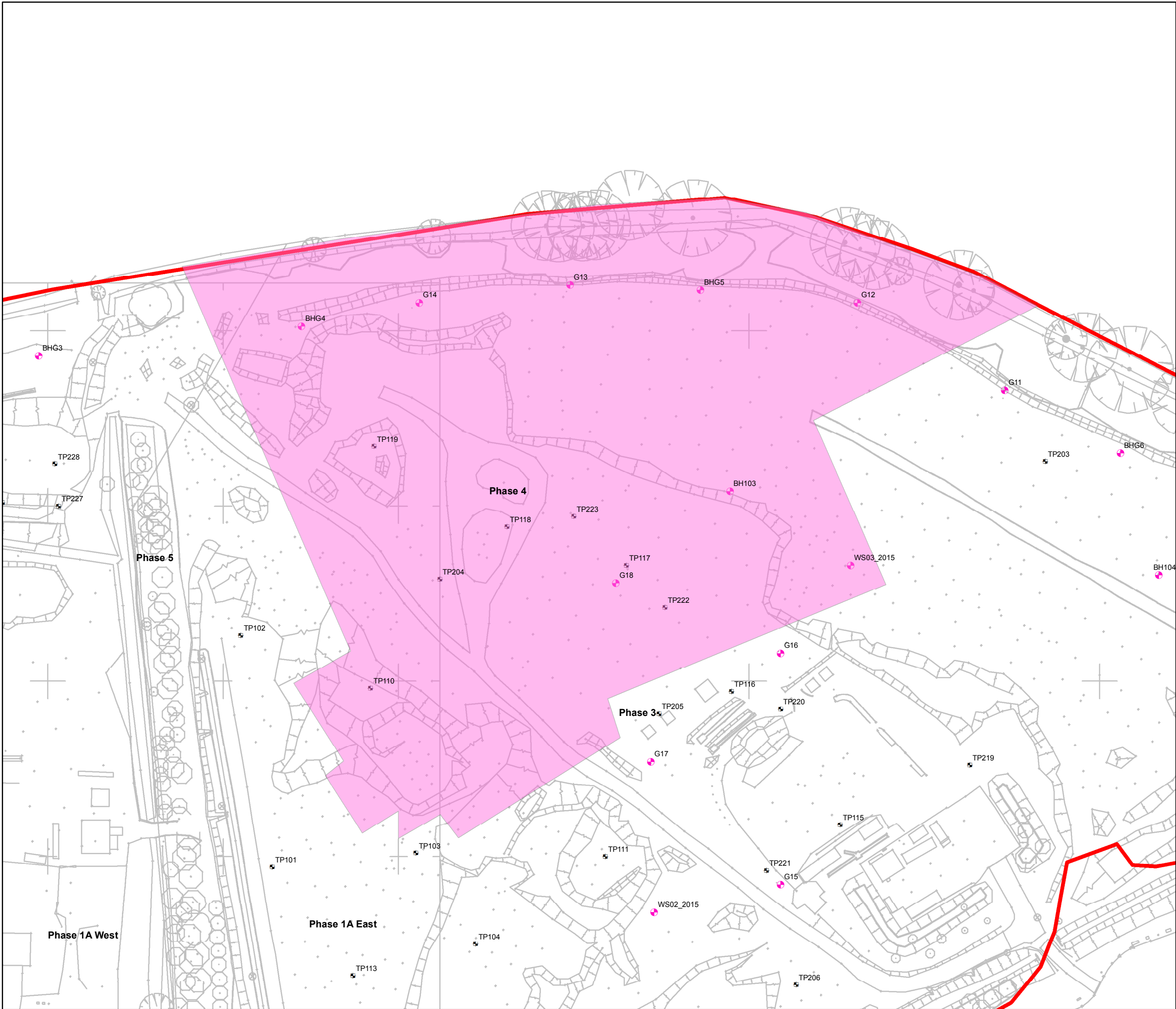
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Figure No.
Figure 7

Revision
01



-  Site Boundary
-  Phase 4
-  Borehole (BH)
-  Trial Pit (TP)



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**Phase 4 Historic Ground
Investigation Plan**



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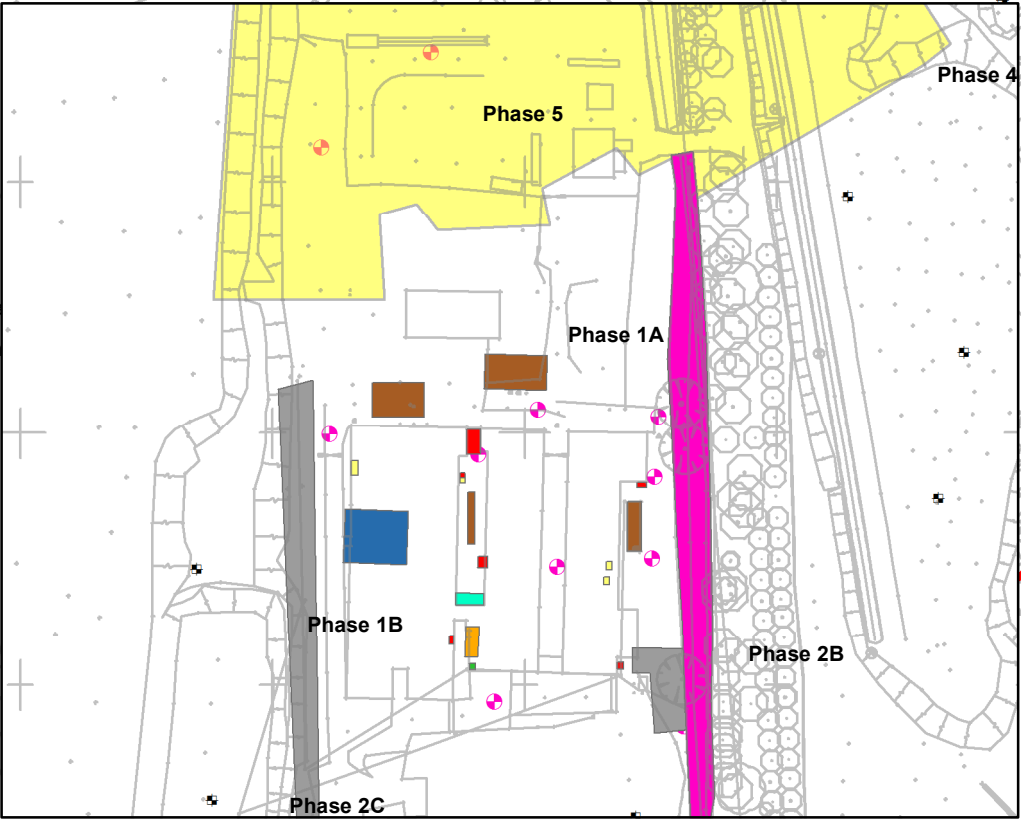
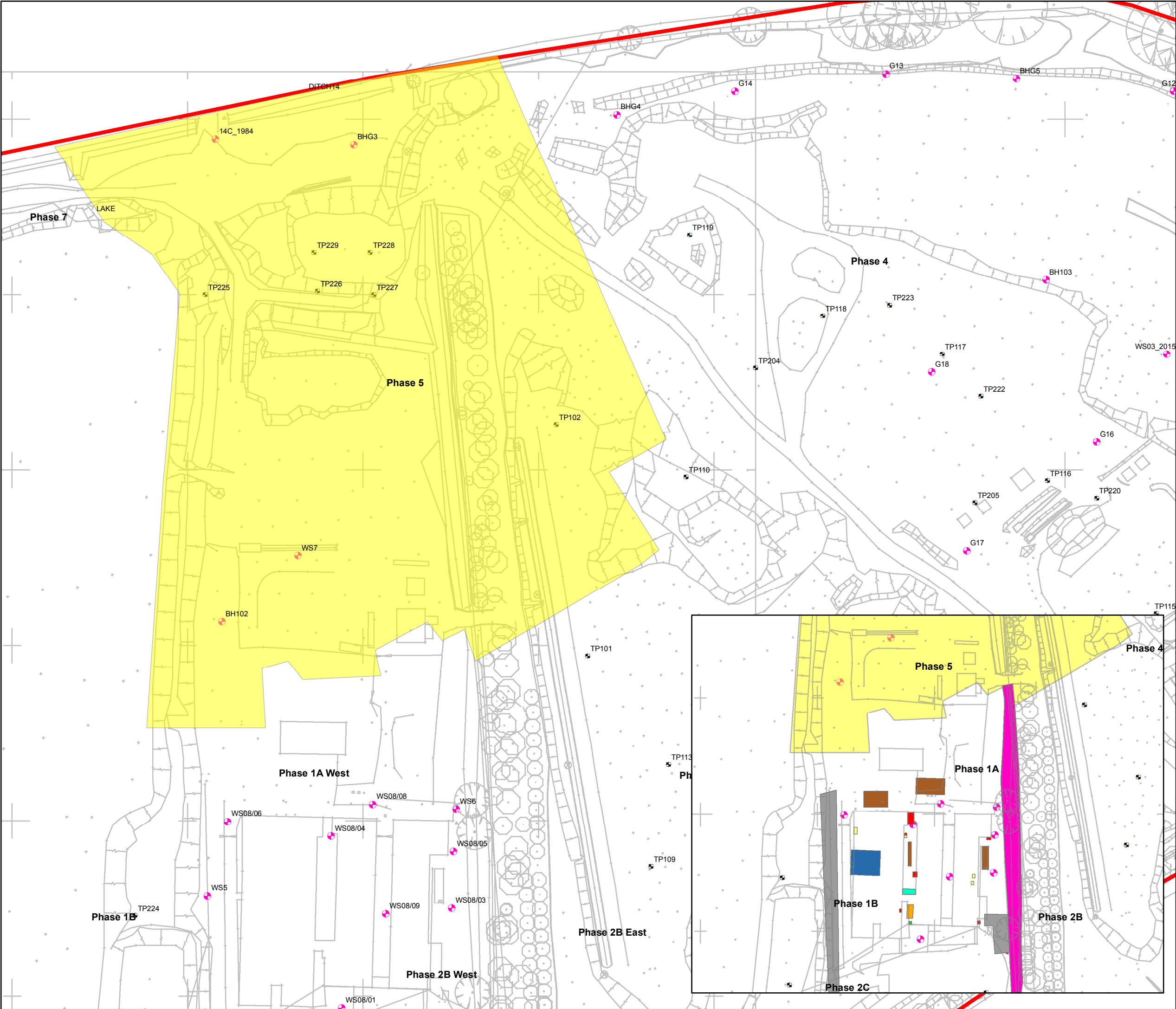
southampton@ramboll.co.uk
www.ramboll.co.uk

Date
March 2016

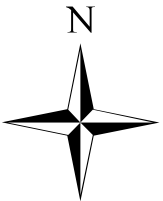
Prepared By
BH

Figure No.
Figure 8

Revision
01



- Site Boundary
- Phase 5
- Borehole (BH)
- Trial Pit (TP)
- Pingemead Potential Sources**
 - AST Diesel / Fuel Oil
 - Blocked Ditch
 - Cesspit
 - Chemical Storage
 - Chemical Waste
 - Historic Abstraction Well
 - Oil Drums
 - Paint Mixing and Storage
 - Paint Spray Booth
 - Uncontrolled Waste



1:1,000
Drawn at A3

Client

**St Edward
Homes Ltd**

Project Title

Green Park Village

Project Number

1620000492

Figure Title

**Phase 5 Historic Ground
Investigation Plan**



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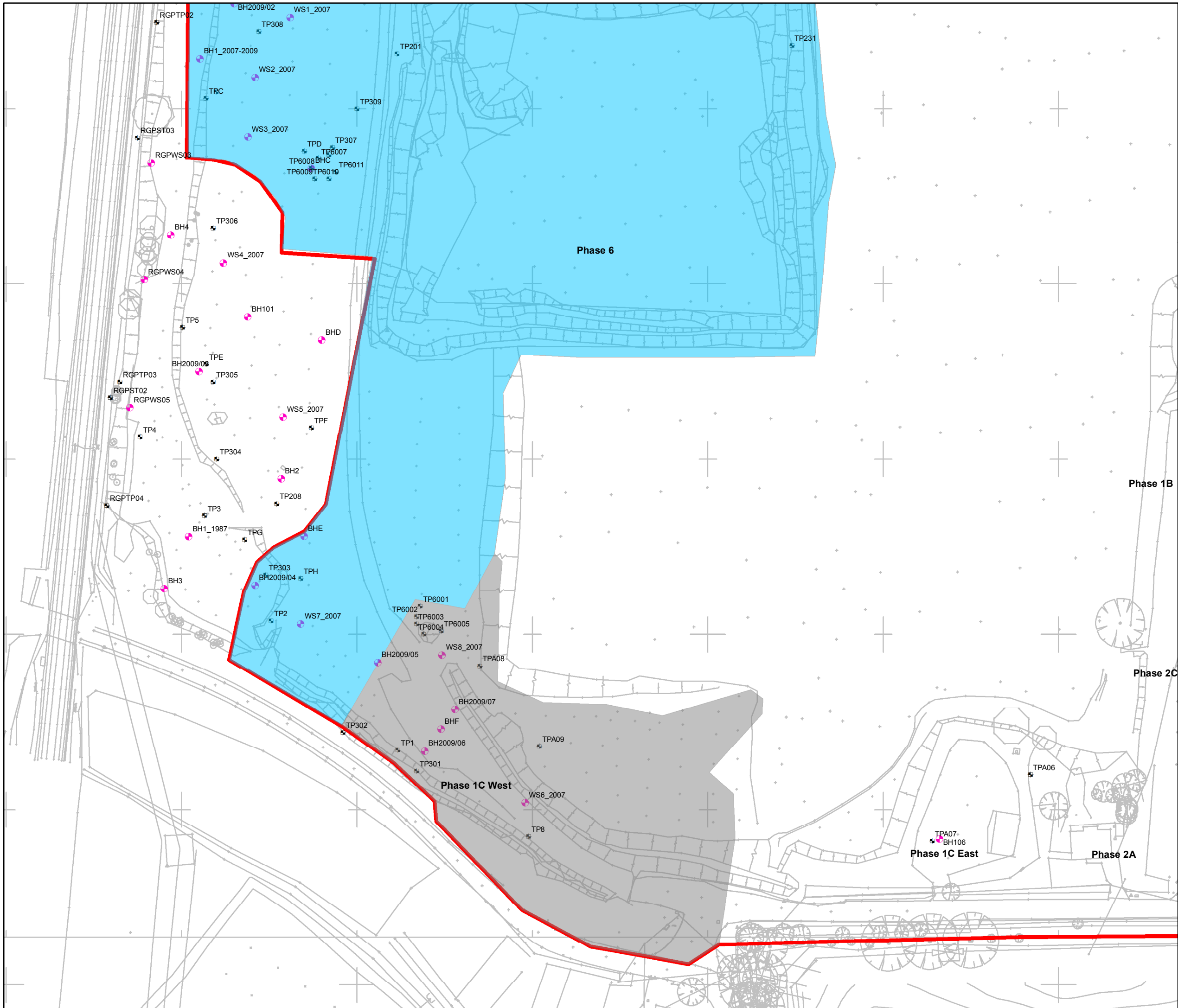
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Date
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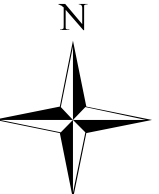
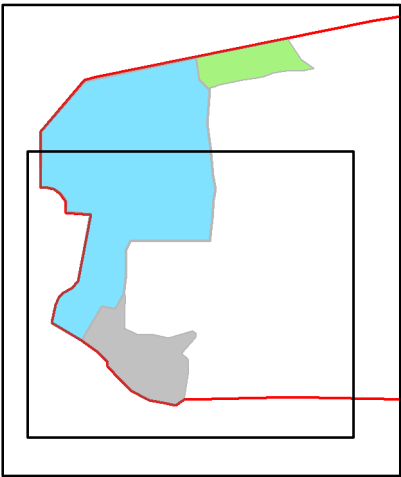
Prepared By
BH

Figure No.
Figure 9

Revision
01



- Site Boundary
- Phase 1C West
- Phase 6
- Phase 7
- Borehole (BH)
- Trial Pit (TP)



1:1,000
Drawn at A3

Client

**St Edward
Homes Ltd**

Project Title

Green Park Village

Project Number

1620000492

Figure Title

**Phase 1C West and Phase 6
Historic Ground Investigation
Plan - South**



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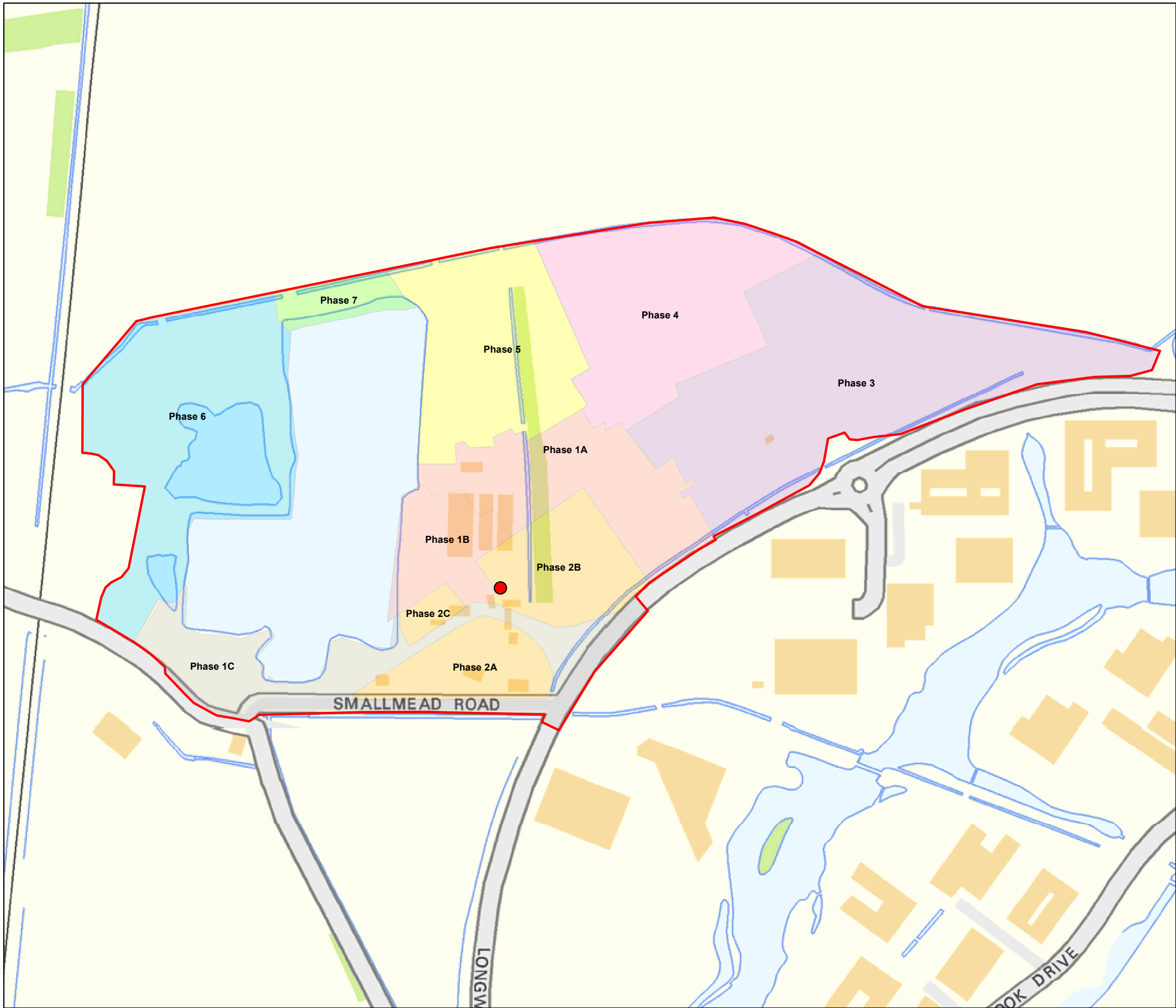
BH

Figure No.

Figure 11

Revision

01



Site Boundary

Phase

- Phase 1A
- Phase 1B
- Phase 1C
- Phase 2A
- Phase 2B
- Phase 2C
- Phase 3
- Phase 4
- Phase 5
- Phase 6
- Phase 7

Asbestos in soils



1:3,000

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Project Title

Green Park Village

Project Number

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Figure Title

Abestos in Soil Plan



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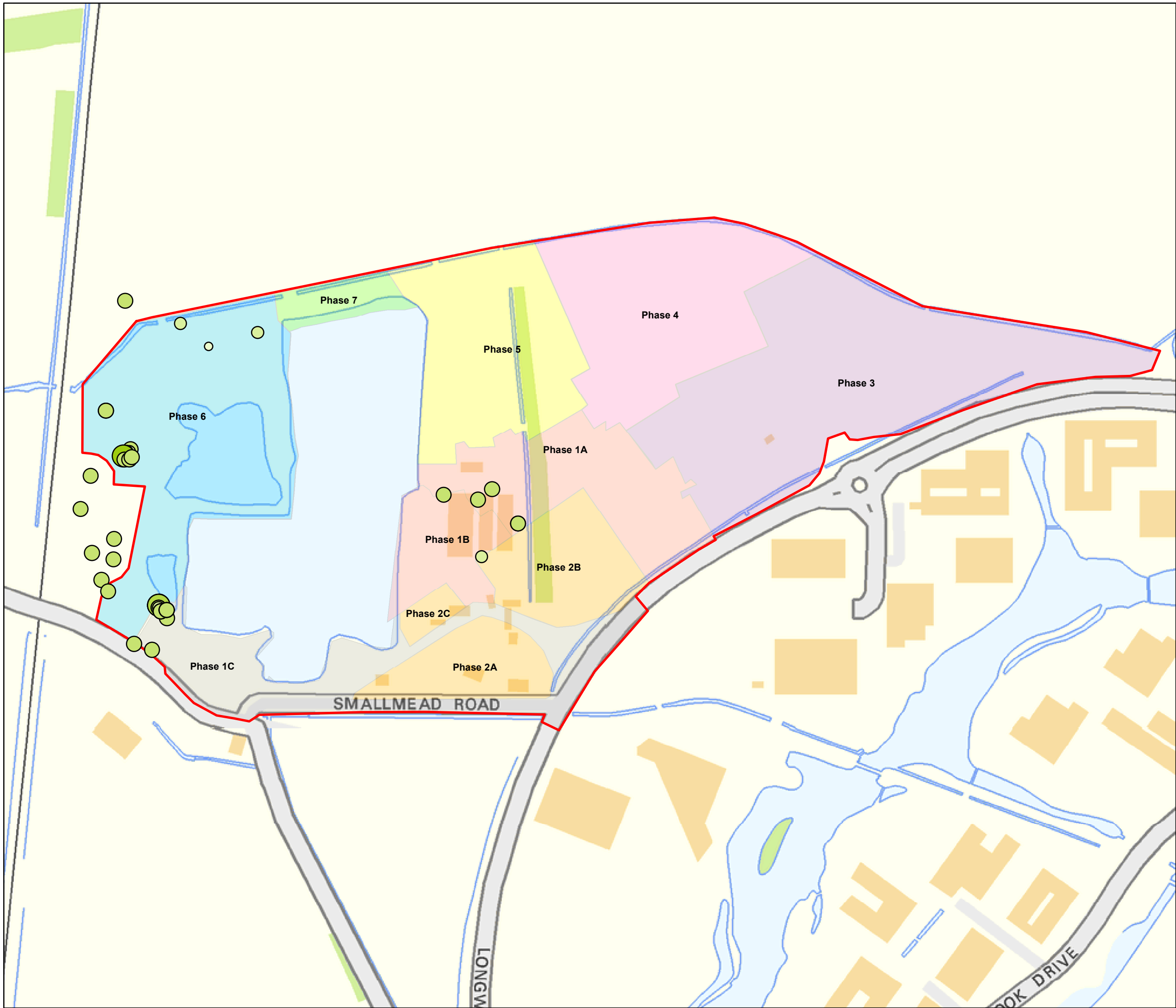
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March 2016

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Figure No.
Figure 12

Revision
01



Site Boundary

Phase

- Phase 1A
- Phase 1B
- Phase 1C
- Phase 2A
- Phase 2B
- Phase 2C
- Phase 3
- Phase 4
- Phase 5
- Phase 6
- Phase 7

Total Cr mg/kg

- <21
- 21-23
- 23-49
- 49-100
- >100

1:3,000

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Project Title

Green Park Village

Project Number

1620000492

Figure Title

Chromium - Soils Plan



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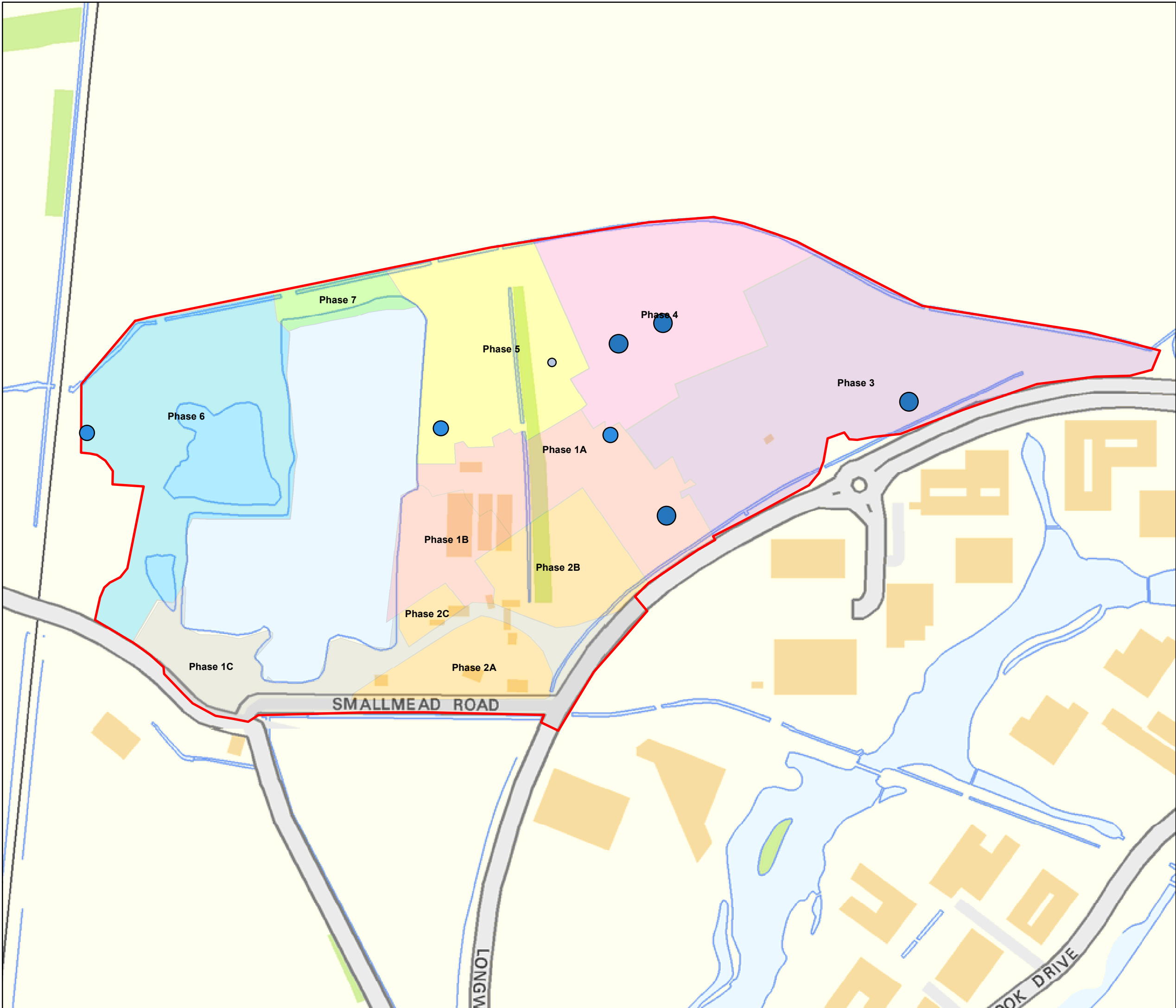
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March 2016

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Figure No.
Figure 13

Revision
01



Site Boundary

Phase

- Phase 1A
- Phase 1B
- Phase 1C
- Phase 2A
- Phase 2B
- Phase 2C
- Phase 3
- Phase 4
- Phase 5
- Phase 6
- Phase 7

Hg mg/kg

- <1
- 1-1.2
- 1.2-2
- 2-3
- >3

1:3,000

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Client

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Project Title

Green Park Village

Project Number

1620000492

Figure Title

Mercury - Soils Plan



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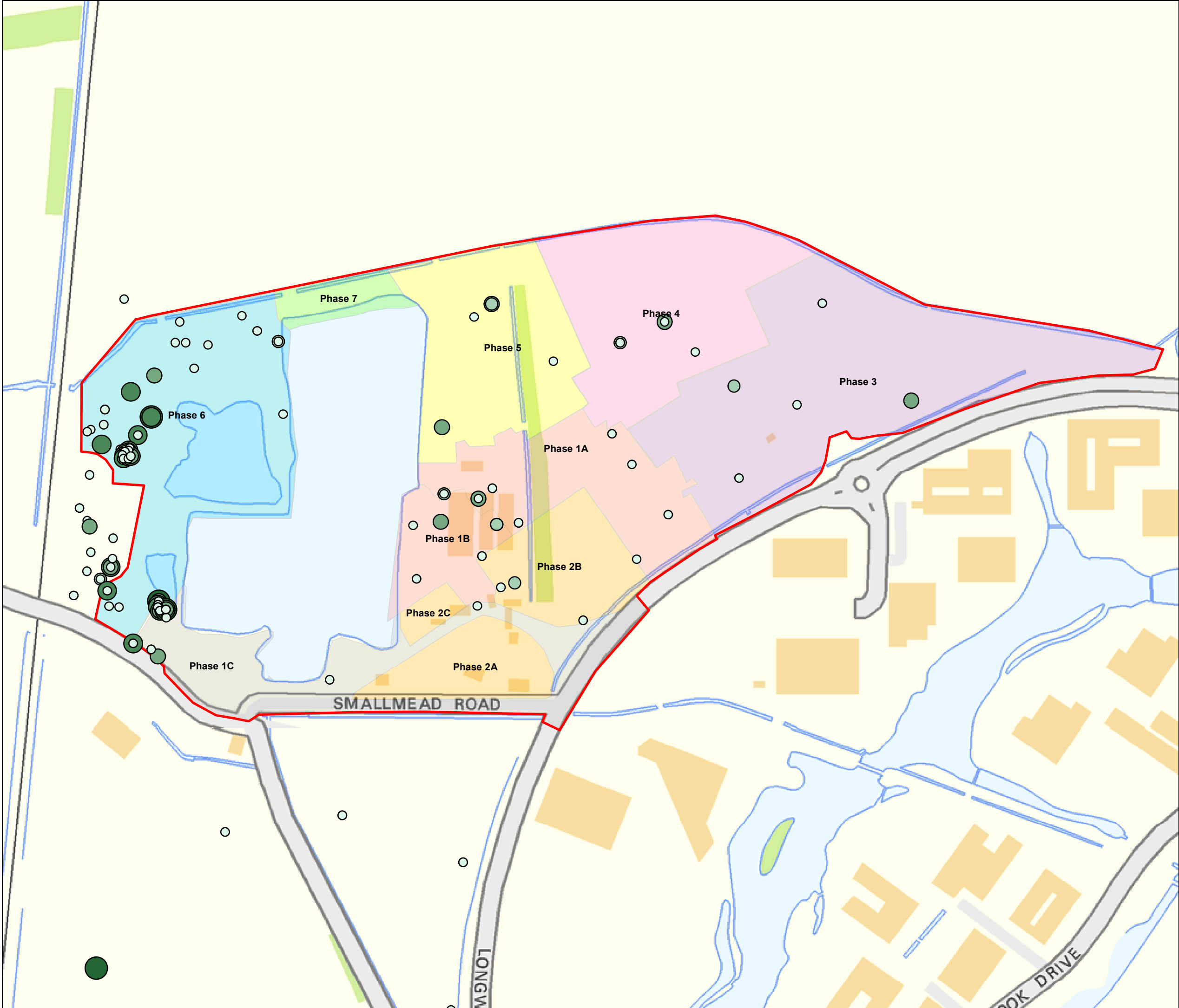
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Figure No.
Figure 14

Revision
01



Site Boundary

Phase

- Phase 1A
- Phase 1B
- Phase 1C
- Phase 2A
- Phase 2B
- Phase 2C
- Phase 3
- Phase 4
- Phase 5
- Phase 6
- Phase 7

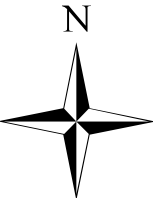
Pb mg/kg

- <200
- 200-310
- 310-630
- 630-2300
- >2300

1:3,000

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Client

**St Edward
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Project Title

Green Park Village

Project Number

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Figure Title

Lead - Soils Plan



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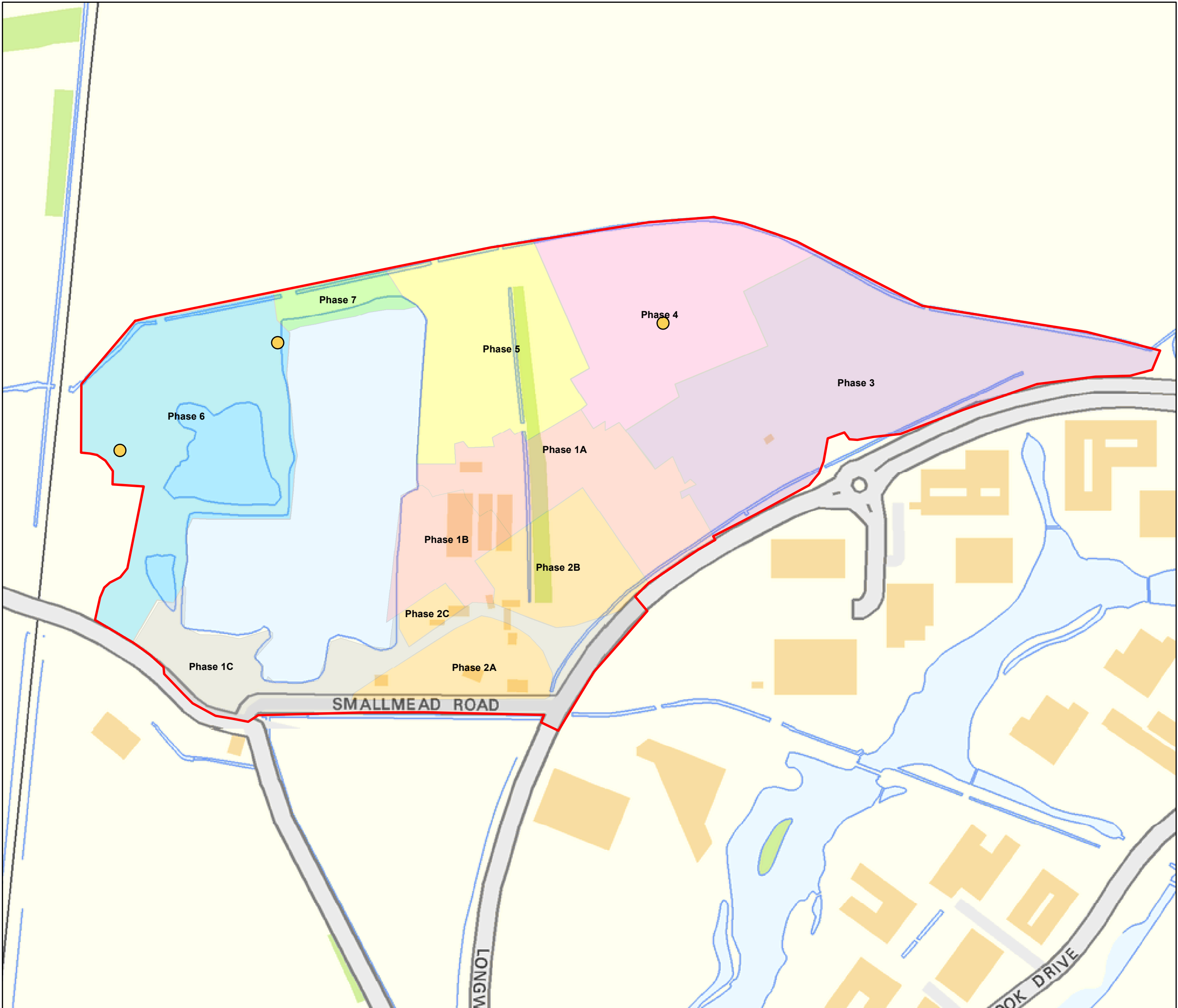
BH

Figure No.

Figure 15

Revision

01



Site Boundary

Phase

- Phase 1A
- Phase 1B
- Phase 1C
- Phase 2A
- Phase 2B
- Phase 2C
- Phase 3
- Phase 4
- Phase 5
- Phase 6
- Phase 7

Naphthalene mg/kg

- 2.4 - 2.3
- 2.3-76.4
- 76.4-190
- 190-1200
- >1200

1:3,000

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Project Title

Green Park Village

Project Number

1620000492

Figure Title

PAH (Naphthalene) - Soils Plan



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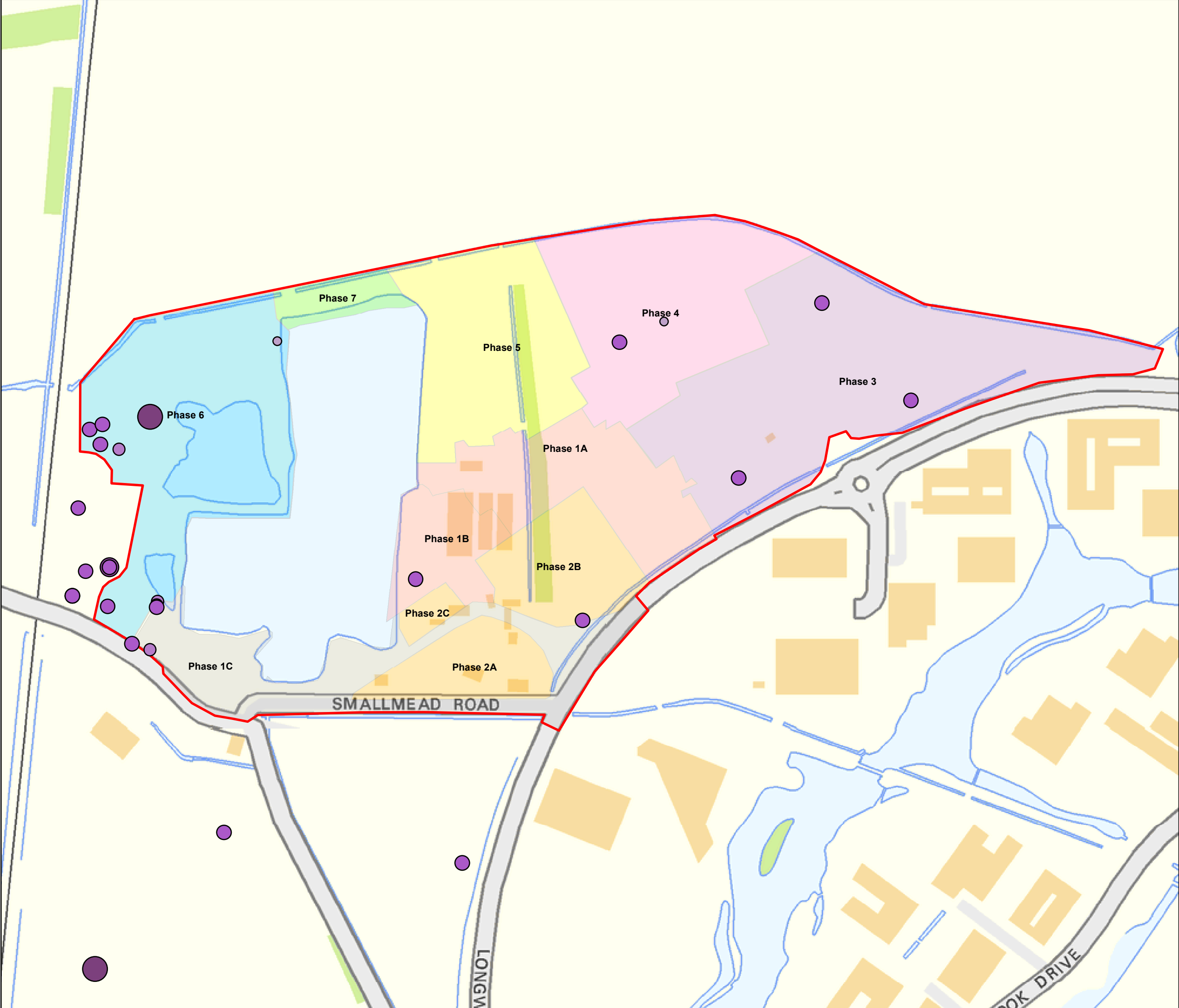
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Figure No.

Figure 16

Revision

01



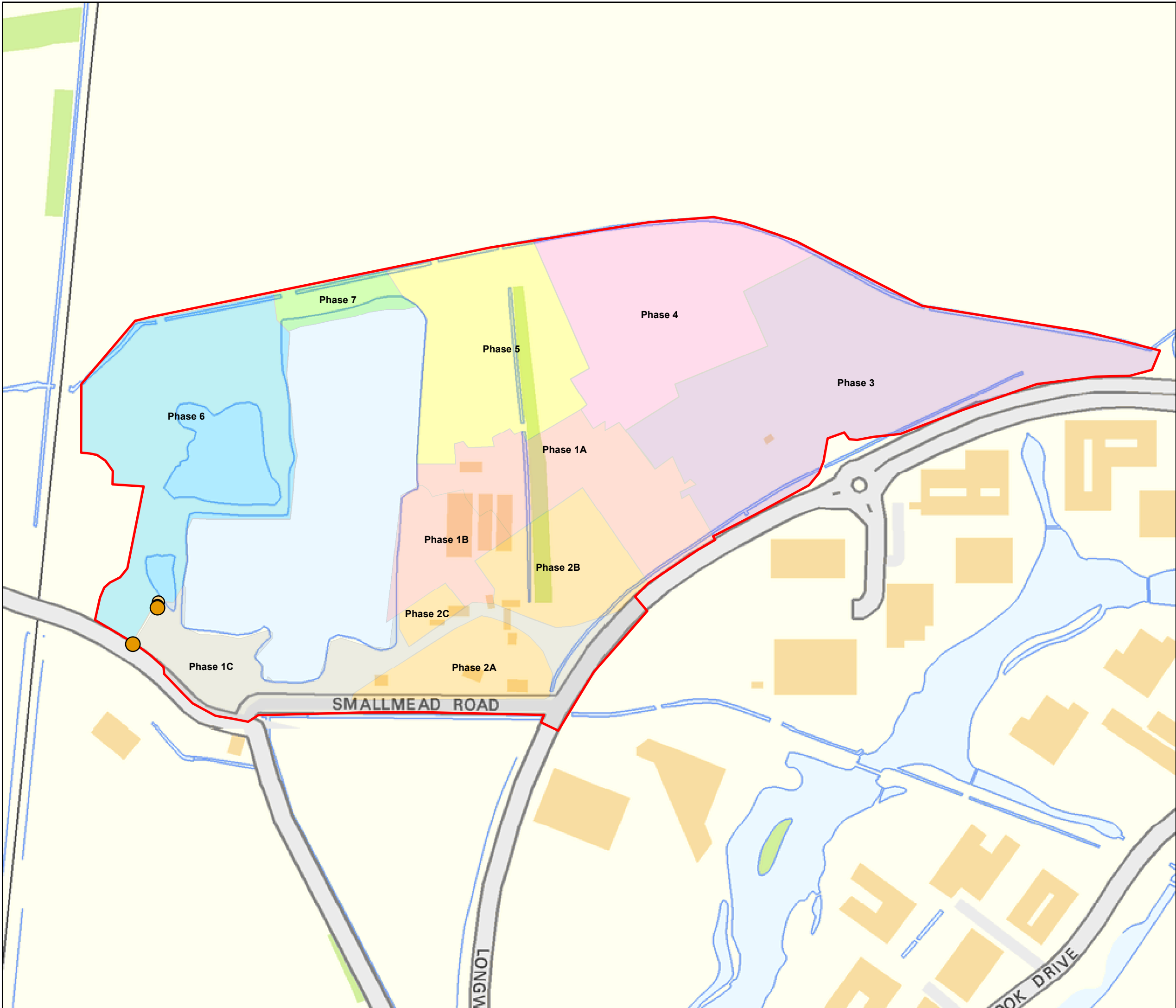
- Site Boundary**
- Phase**
- Phase 1A
 - Phase 1B
 - Phase 1C
 - Phase 2A
 - Phase 2B
 - Phase 2C
 - Phase 3
 - Phase 4
 - Phase 5
 - Phase 6
 - Phase 7

- PAH mg/kg**
- <5
 - 5-10
 - 10-76
 - 76-1000
 - >1000

1:3,000
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Client St Edward Homes Ltd	
Project Title Green Park Village	
Project Number 1620000492	
Figure Title PAH (Total) - Soils Plan	
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Date March 2016	Prepared By BH
Figure No. Figure 17	Revision 01



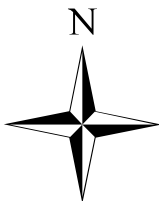
Site Boundary

Phase

- Phase 1A
- Phase 1B
- Phase 1C
- Phase 2A
- Phase 2B
- Phase 2C
- Phase 3
- Phase 4
- Phase 5
- Phase 6
- Phase 7

BaP mg/kg

- <5
- 5-10
- 10-76



1:3,000

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Green Park Village

Project Number

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Figure Title

**PAH (Benzo a pyrene) - Soils
Plan**



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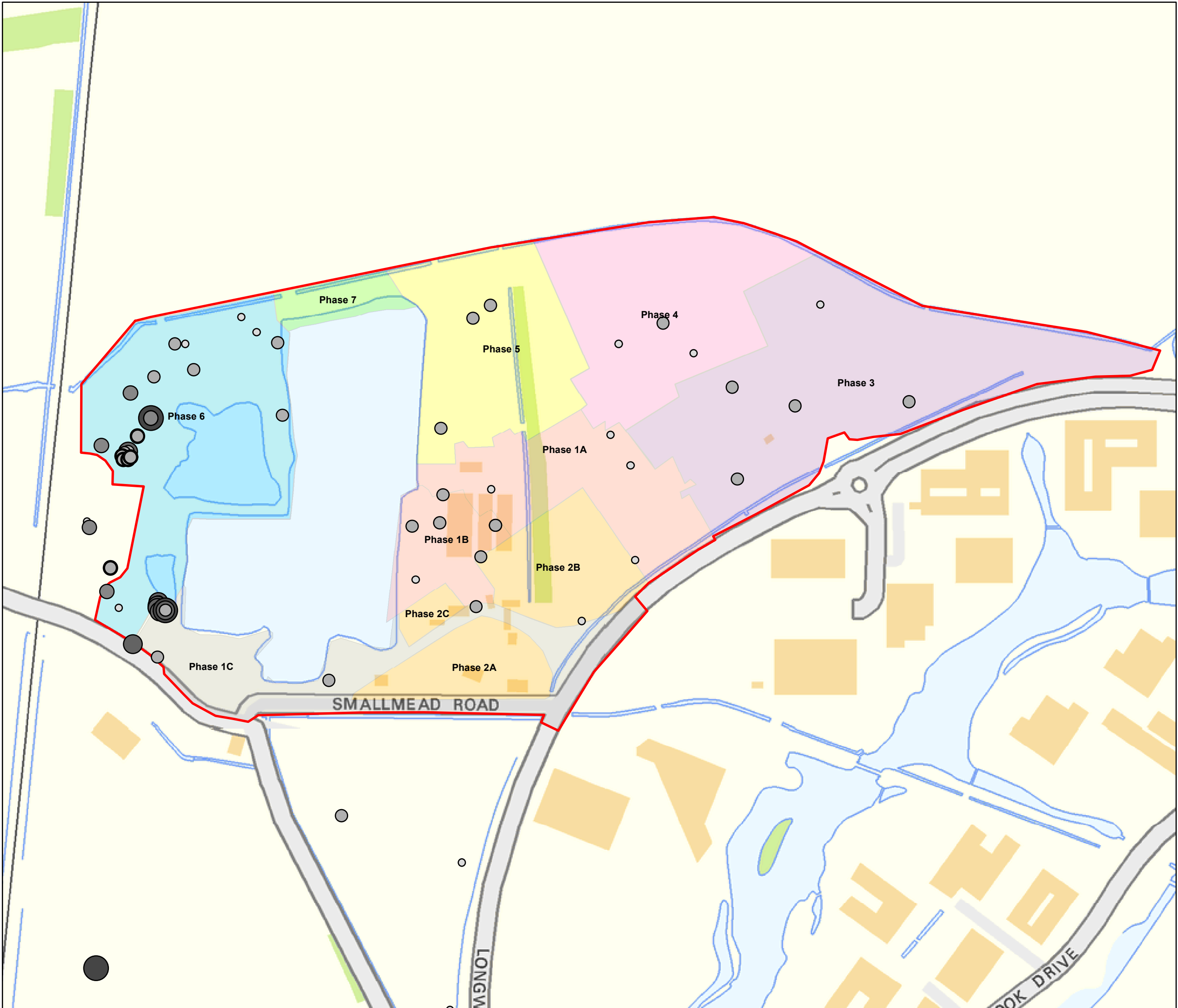
BH

Figure No.

Figure 18

Revision

01



Site Boundary

Phase

- Phase 1A
- Phase 1B
- Phase 1C
- Phase 2A
- Phase 2B
- Phase 2C
- Phase 3
- Phase 4
- Phase 5
- Phase 6
- Phase 7

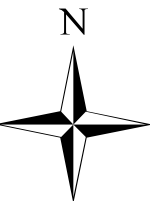
Total TPH mg/kg

- <100
- 100-500
- 500-1000
- 100-2500
- 2500-5000

1:3,000

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Project Title

Green Park Village

Project Number

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Figure Title

TPH - Soils Plan



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Date

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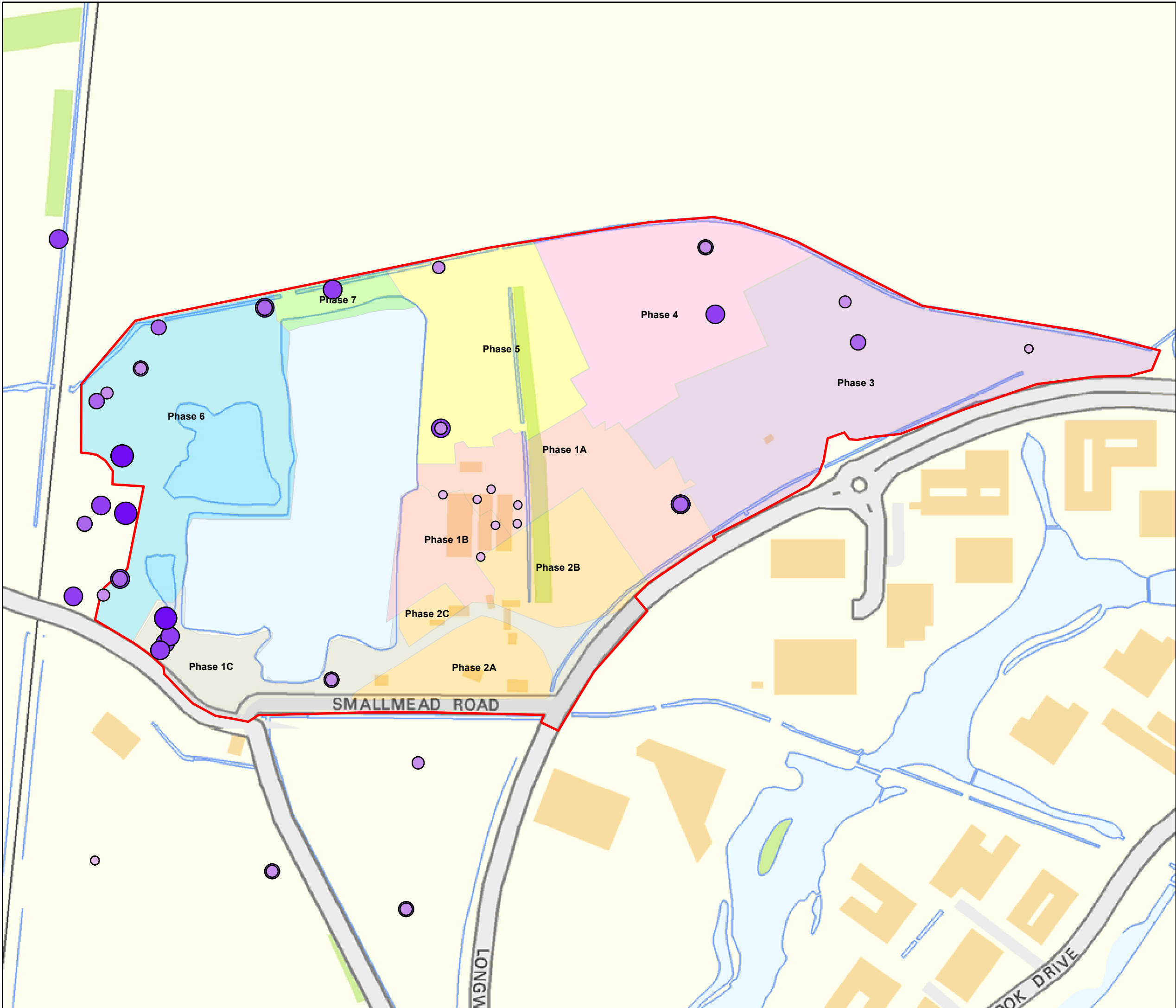
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Figure No.

Figure 19

Revision

01



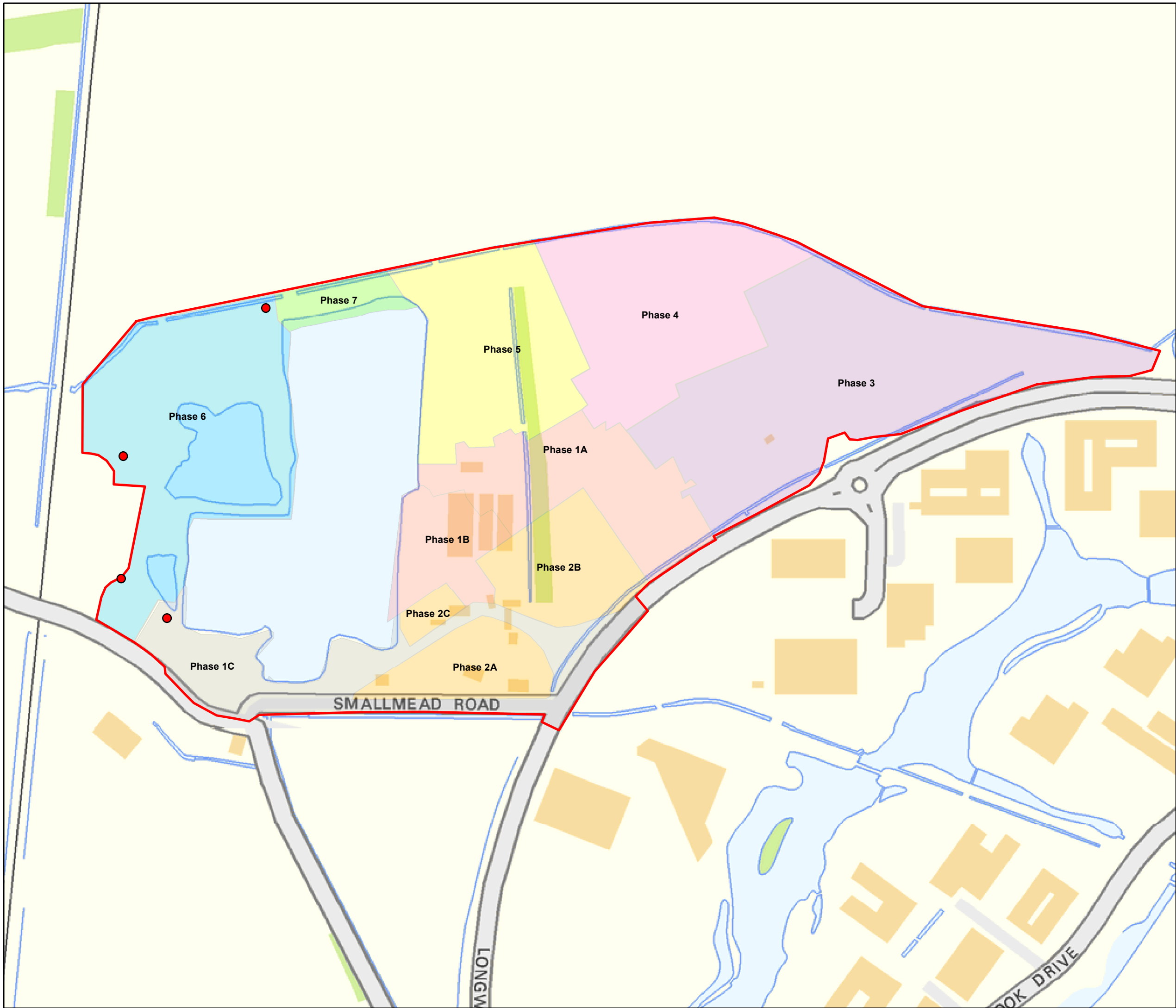
- Site Boundary**
- Phase**
- Phase 1A
 - Phase 1B
 - Phase 1C
 - Phase 2A
 - Phase 2B
 - Phase 2C
 - Phase 3
 - Phase 4
 - Phase 5
 - Phase 6
 - Phase 7

- Ammonia ug/l**
- <300
 - 300-600
 - 600-1000
 - 1000-10,000
 - >10,000

1:3,000
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Project Title Green Park Village	
Project Number 1620000492	
Figure Title Ammonia - Groundwater Plan	
	
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Figure No. Figure 20	Revision 01



Site Boundary

Phase

- Phase 1A
- Phase 1B
- Phase 1C
- Phase 2A
- Phase 2B
- Phase 2C
- Phase 3
- Phase 4
- Phase 5
- Phase 6
- Phase 7

Cd ug/l

1



1:3,000

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**St Edward
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Project Title

Green Park Village

Project Number

1620000492

Figure Title

Cadmium - Groundwater Plan



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March 2016

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Figure No.

Figure 21

Revision

01



Site Boundary

Phase

- Phase 1A
- Phase 1B
- Phase 1C
- Phase 2A
- Phase 2B
- Phase 2C
- Phase 3
- Phase 4
- Phase 5
- Phase 6
- Phase 7

Cr ug/l

- <3.4
- 3.4-4.7
- 4.7-10
- 10-20
- >20

1:3,000

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Client

**St Edward
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Project Title

Green Park Village

Project Number

1620000492

Figure Title

Chromium - Groundwater Plan



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Date

March 2016

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Figure No.

Figure 22

Revision

01

DRAWINGS

PL-MPL-005 - Illustrative Master Plan

4140564-1101 – Plan Layout of Proposed Development Sections

4140564-1102 - Proposed Levels Development Sections (Sheet 1 of 3)

4140564-1103 - Proposed Levels Development Sections (Sheet 2 of 3)

4140564-1104 - Proposed Levels Development Sections (Sheet 3 of 3)

1620000492-RAM-GDR-00-DR-CG-001 – Exploratory Hole Location Plan

1620000492-RAM-GDR-XX-DR-CG-002 – Geological Section A-A' Plan

1620000492-RAM-GDR-XX-DR-CG-003 - Geological Section B-B' and C-C' Plan

1620000492-RAM-GDR-XX-DR-CG-004 - Geological Section D-D' and E-E' Plan

1620000492-RAM-GDR-XX-DR-CG-005 - Geological Section F-F' and G-G' Plan



LANDSCAPING SHOWN IS INDICATIVE
SEE 'PLACE' LANDSCAPE PROPOSALS FOR DETAILS

Contractors are not to scale dimensions from
this drawing

The internal layouts within apartments will be subject to
design development.
The precise location of walls and internal doors and the
detailed layout of bathroom and kitchen areas will be
subject of non-material changes and may vary from the
internal layouts set out in these plans.
These minor alterations will not affect the pollution and
arrangement to external doors and windows nor will they
affect the relative relationship between habitable rooms
and windows.

The survey information shown on this drawing is based
on a topographical survey prepared by a third party and
Broadway Malyan Limited accept no responsibility for the
accuracy or completeness of the survey.

Rev	Description	Drawn	Check	App'd	Date
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BroadwayMalyan^{BAM}

Architecture Urbanism Design

Box House, 10 High Street
Thames, Reading
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T: +44 (0)118 932 3456
F: +44 (0)118 932 3461
E: Ray@BroadwayMalyan.com

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Client
St. Edward Homes

Project
Green Park Village

Description
Illustrative masterplan

Status PLANNING APPLICATION

Scale Drawn Date
1:1000@A0 dc May 2010

Job number Drawing number Revision
27429 PL-MPL-005 P-

Original size 210mm @ A0 Copyright Broadway Malyan Limited



This drawing should not be scaled. For construction purposes work to figured dimensions only

0mm

40mm

80mm

ORIGINAL SHEET SIZE

A1

NOTES

1. THIS DRAWING IS TO BE READ IN CONJUNCTION WITH ALL OTHER DETAIL DESIGN DRAWINGS AND SPECIFICATIONS. DISCREPANCIES FOUND BETWEEN INFORMATION SHOWN ON THIS AND ANY OTHER DRAWING SHALL BE REPORTED TO GLANVILLE'S ENGINEER.
2. FINAL DETAILED LEVELS WILL VARY SLIGHTLY TO FACILITATE THE PROPOSED DRAINAGE IN PAVED AREAS.

P1	PRELIMINARY ISSUE	02/06/15	MG
Rev.	Description	Date	Chkd



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Hemel Hempstead, Herts. HP2 7TE
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postbox@glanvillegroup.com www.glanvillegroup.com

Client :



Designed for life

Project :

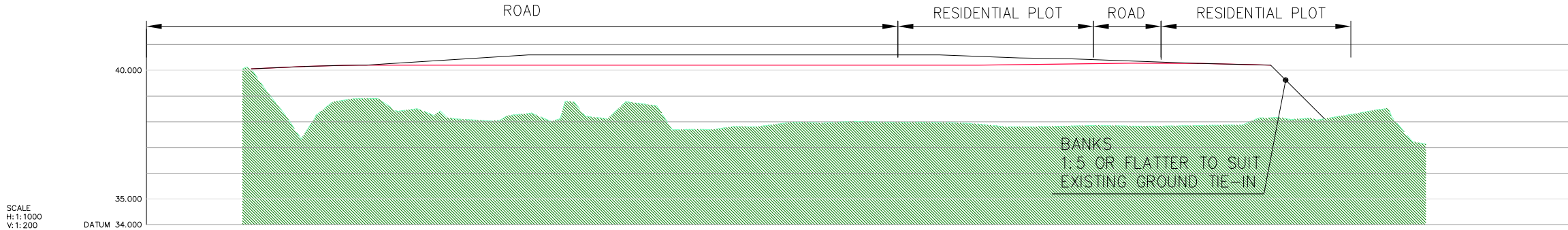
GREEN PARK VILLAGE
READING

Title :

PLAN LAYOUT OF PROPOSED
DEVELOPMENT SECTIONS

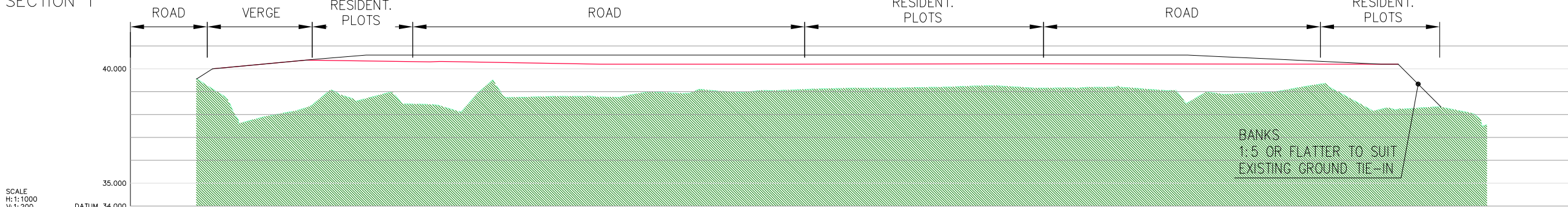
Project Engineer :	MG	Scale :	1:1000 @ A1
Project Director :	HBG	Date :	JUNE 2015
Status :	PRELIMINARY		

Drawing No.	4140564-1101	Rev	P1
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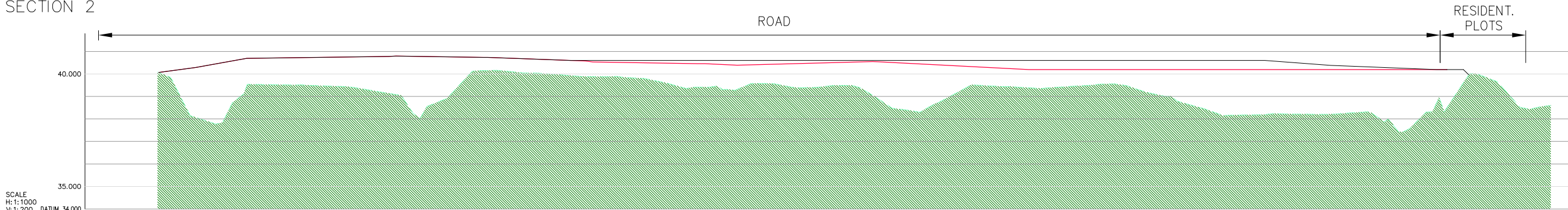
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EXISTING GROUND LEVEL			40.082	37.349	38.889	38.436	38.112	38.217	38.090	38.186	38.368	37.696	37.836	37.955	38.004	37.976	37.931	37.804	37.834	37.836	37.838	37.868	38.173	38.149	38.483				
GLANVILLE EARTHWORKS LEVEL					40.196	40.293	40.420	40.547	40.600	40.600	40.600	40.600	40.600	40.600	40.600	40.600	40.553	40.474	40.440	40.368	40.295	40.230	40.200						
PBA EARTHWORKS LEVEL					40.196	40.200	40.200	40.199	40.200	40.200	40.200	40.200	40.200	40.200	40.200	40.200	40.200	40.222	40.248	40.274	40.268	40.230							

SECTION 1



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SECTION 2



CHAINAGE	0.000	10.000	20.000	30.000	40.000	50.000	60.000	70.000	80.000	90.000	100.000	110.000	120.000	130.000	140.000	150.000	160.000	170.000	180.000	190.000	200.000	210.000	220.000	230.000	240.000	250.000	260.000	270.000	280.000	290.000	300.000	310.000	320.000	330.000
EXISTING GROUND LEVEL			39.461	37.816	39.530	39.494	39.388	39.054	38.881	40.157	40.041	39.892	39.846	39.550	39.454	39.577	39.395	39.492	38.460	38.774	39.483	39.384	39.460	39.521	39.010	38.353	38.183	38.214	38.253	37.865	38.635	39.938	38.468	37.854
GLANVILLE EARTHWORKS LEVEL			40.166	40.484	40.709	40.735	40.761	40.794	40.763	40.731	40.657	40.600	40.600	40.600	40.600	40.600	40.600	40.600	40.600	40.600	40.600	40.600	40.600	40.600	40.600	40.600	40.480	40.353	40.278	40.202				
PBA EARTHWORKS LEVEL			40.166	40.484	40.709	40.735	40.761	40.794	40.763	40.731	40.657	40.594	40.515	40.482	40.438	40.415	40.469	40.523	40.504	40.401	40.299	40.200	40.200	40.200	40.200	40.200	40.200	40.200	40.200	40.200				

SECTION 3

This drawing should not be scaled. For construction purposes work to figured dimensions only



NOTES

1. THIS DRAWING IS TO BE READ IN CONJUNCTION WITH ALL OTHER DETAIL DESIGN DRAWINGS AND SPECIFICATIONS. DISCREPANCIES FOUND BETWEEN INFORMATION SHOWN ON THIS AND ANY OTHER DRAWING SHALL BE REPORTED TO GLANVILLE'S ENGINEER.
2. FINAL DETAILED LEVELS WILL VARY SLIGHTLY TO FACILITATE THE PROPOSED DRAINAGE IN PAVED AREAS.

KEY:

- EXISTING GROUND LEVEL
- GLANVILLE EARTHWORKS LEVEL
- PBA EARTHWORKS LEVEL

P1	PRELIMINARY ISSUE	02/06/15	MG
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Rev.	Description	Date	Chkd
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Glanville
3 Grovelands Business Centre
Boundary Way
Hemel Hempstead, Herts. HP2 7TE
Tel: (01442) 835999 Fax: (01442) 258924
postbox@glanvillegroup.com www.glanvillegroup.com

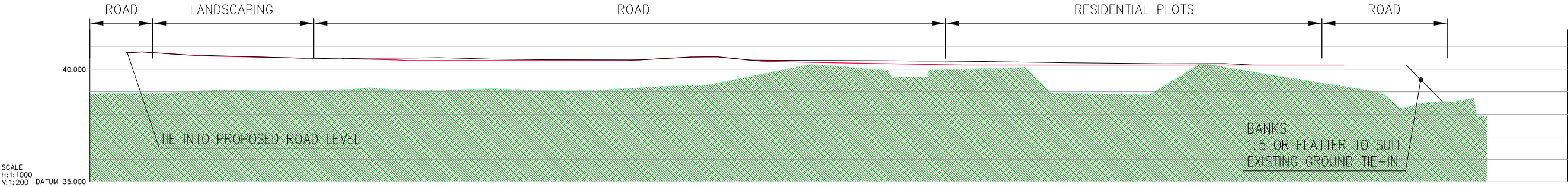
Client : **Berkeley**
Designed for life

Project : GREEN PARK VILLAGE
READING

Title : PROPOSED LEVELS
DEVELOPMENT SECTIONS
SHEET 1 OF 3

Project Engineer :	MG	Scale :	AS SHOWN
Project Director :	HGB	Date :	JUNE 2015
Status :	PRELIMINARY		

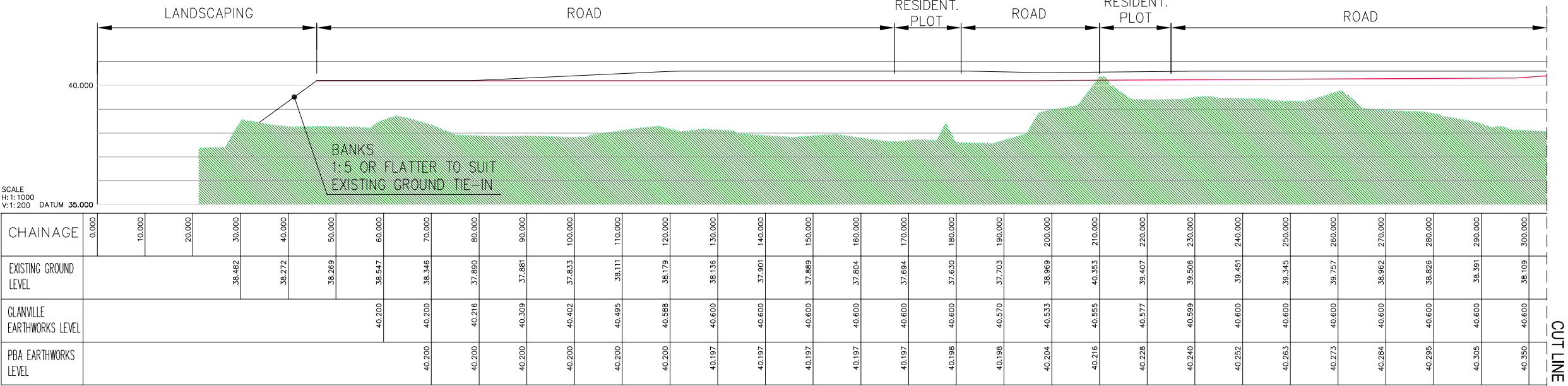
Drawing No.	4140564-1102	Rev	P1
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SCALE
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V: 1:200 DATUM 35.000

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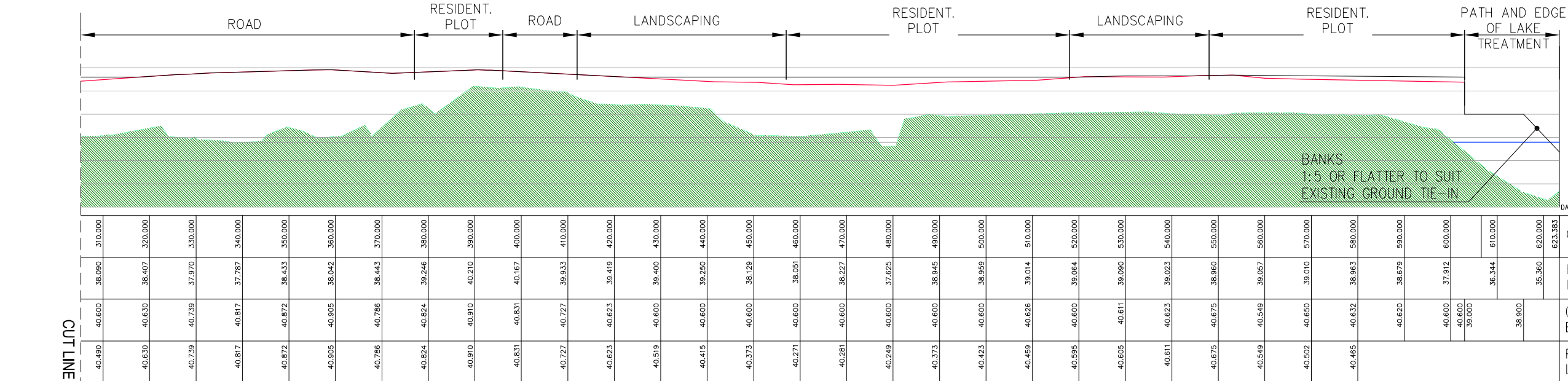
SECTION 4



SCALE
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V: 1:200 DATUM 35.000

CHAINAGE	0.000	10.000	20.000	30.000	40.000	50.000	60.000	70.000	80.000	90.000	100.000	110.000	120.000	130.000	140.000	150.000	160.000	170.000	180.000	190.000	200.000	210.000	220.000	230.000	240.000	250.000	260.000	270.000	280.000	290.000	300.000
EXISTING GROUND LEVEL				38.482	38.272	38.269	38.547	38.346	37.890	37.881	37.833	38.111	38.179	38.136	37.901	37.889	37.804	37.694	37.630	37.703	38.969	40.353	40.553	39.407	39.506	39.451	39.757	38.962	38.626	38.391	38.109
GLANVILLE EARTHWORKS LEVEL				40.200	40.200	40.216	40.309	40.200	40.200	40.200	40.402	40.495	40.598	40.600	40.600	40.600	40.600	40.600	40.600	40.570	40.533	40.555	40.577	40.599	40.600	40.600	40.600	40.600	40.600	40.600	40.600
PBA EARTHWORKS LEVEL				40.200	40.200	40.200	40.200	40.200	40.200	40.200	40.200	40.200	40.200	40.197	40.197	40.197	40.197	40.197	40.198	40.198	40.204	40.218	40.228	40.240	40.252	40.263	40.273	40.284	40.295	40.305	40.350

SECTION A-part 1



SCALE
H: 1:1000
V: 1:200 DATUM 35.000

CUT LINE	CHAINAGE		EXISTING GROUND LEVEL		GLANVILLE EARTHWORKS LEVEL		PBA EARTHWORKS LEVEL	
40.490	40.600	38.090	310.000					
40.630	40.630	38.407	320.000					
40.739	40.739	37.970	330.000					
40.817	40.817	37.787	340.000					
40.872	40.872	38.433	350.000					
40.905	40.905	38.042	360.000					
40.786	40.786	38.443	370.000					
40.824	40.824	38.246	380.000					
40.910	40.910	40.210	390.000					
40.831	40.831	40.167	400.000					
40.727	40.727	39.933	410.000					
40.623	40.623	39.419	420.000					
40.519	40.600	39.400	430.000					
40.415	40.600	39.250	440.000					
40.373	40.600	38.129	450.000					
40.271	40.600	38.051	460.000					
40.281	40.600	38.227	470.000					
40.249	40.600	37.625	480.000					
40.373	40.600	38.945	490.000					
40.423	40.600	38.959	500.000					
40.459	40.626	39.014	510.000					
40.595	40.600	39.064	520.000					
40.605	40.611	39.090	530.000					
40.611	40.623	39.023	540.000					
40.675	40.675	38.960	550.000					
40.549	40.549	39.057	560.000					
40.502	40.650	39.010	570.000					
40.465	40.632	38.963	580.000					
	40.620	38.679	590.000					
	40.600	37.912	600.000					
	40.600							
	39.000							
		36.344	610.000					
	38.900							
		35.360	620.000					
		623.383						

SECTION A-part 2

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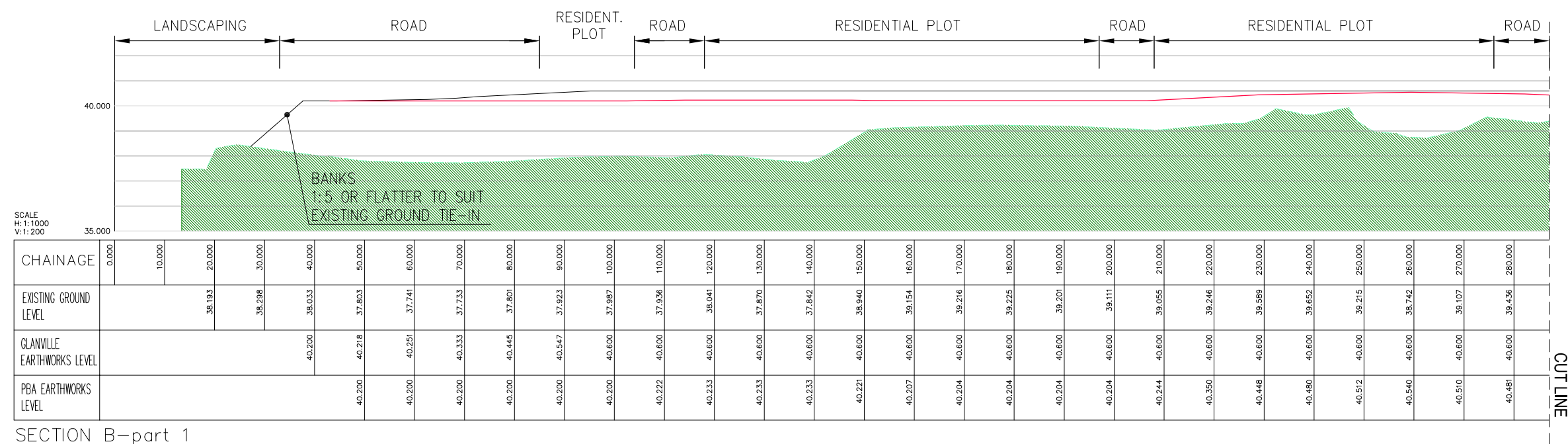
- EXISTING GROUND LEVEL
- GLANVILLE EARTHWORKS LEVEL
- PBA EARTHWORKS LEVEL

P1	PRELIMINARY ISSUE	02/06/15	MG
Rev.	Description	Date	Chkd

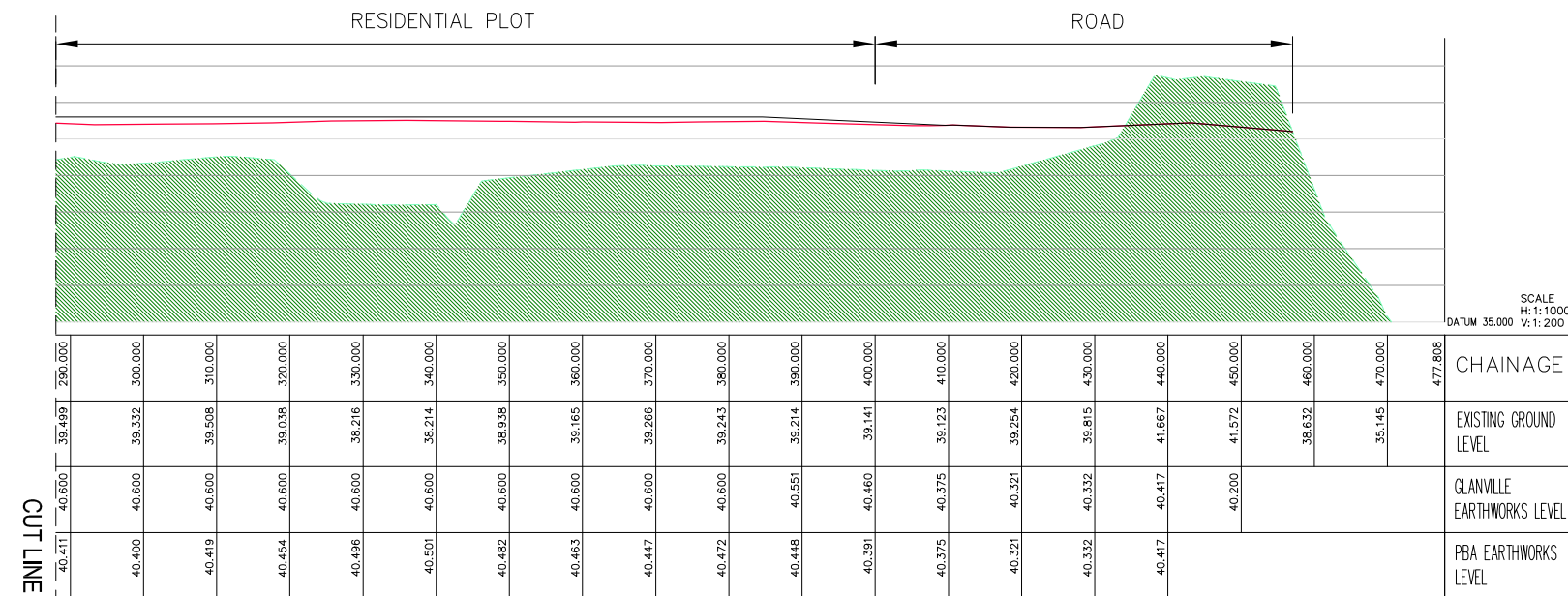
Glanville
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Client :	Berkeley Designed for life
Project :	GREEN PARK VILLAGE READING
Title :	PROPOSED LEVEL DEVELOPMENT SECTIONS SHEET 2 OF 3
Project Engineer :	MG
Project Director :	HBG
Status :	PRELIMINARY

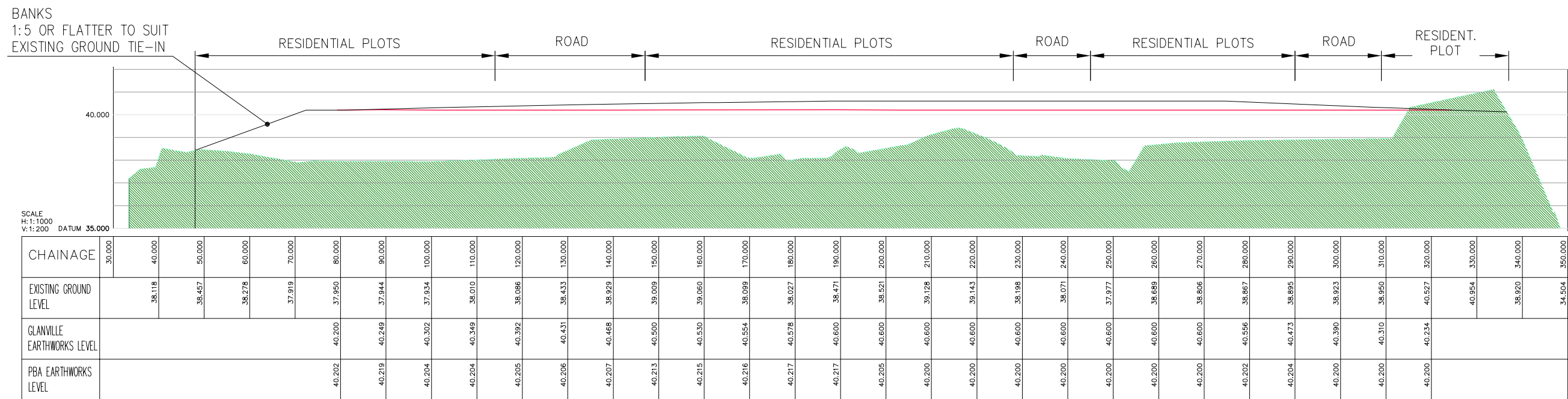
Drawing No.	4140564-1103	Rev	P1
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SECTION B-part 1



SECTION B-part 2



SECTION C

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KEY:

- EXISTING GROUND LEVEL
- GLANVILLE EARTHWORKS LEVEL
- PBA EARTHWORKS LEVEL

P1	PRELIMINARY ISSUE	02/06/15	MG
Rev.	Description	Date	Chkd

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Client : **Berkeley**
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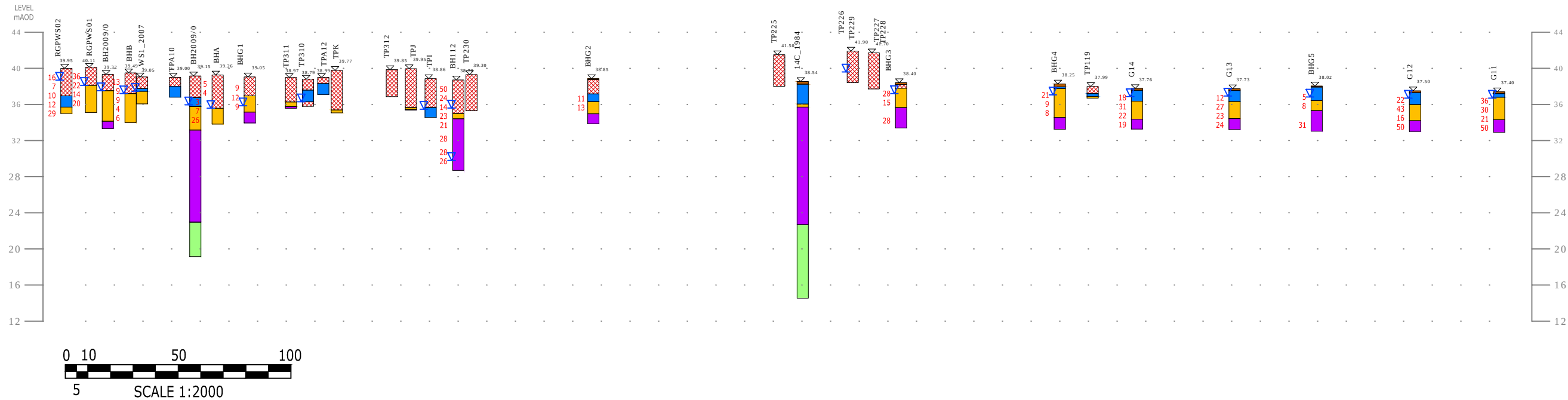
Project : GREEN PARK VILLAGE READING

Title : PROPOSED LEVEL DEVELOPMENT SECTIONS
SHEET 3 OF 3

Project Engineer :	MG	Scale :	AS SHOWN
Project Director :	HBG	Date :	JUNE 2015
Status :	PRELIMINARY		

Drawing No.	4140564-1104	Rev	P1
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 - FOR STRATA DETAILS REFER TO EXPLORATORY HOLE LOGS

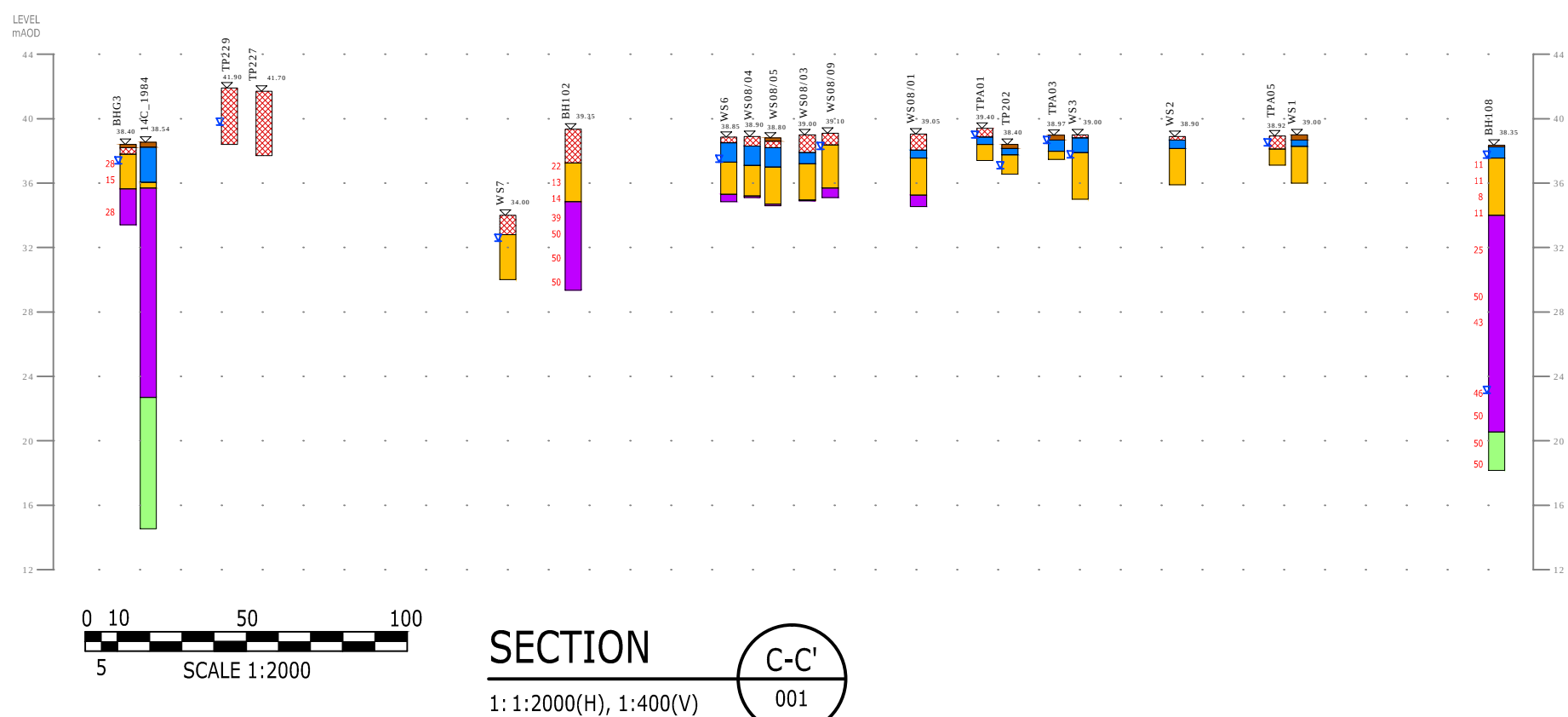


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GREEN PARK VILLAGE
READING

GEOLOGICAL SECTION A-A'

Rev	Description	Date	By Chk	App
FOR INFORMATION				
Project No: 1620000492		Scale (@A3): AS SHOWN	Drawn: SKH	Date: FEB.16
Drawing No: RAM-GDR-XX-DR-CG-002				Rev: I01



- KEY**

	TOPSOIL
	MADE GROUND
	ALLUVIUM
	RIVER TERRACE DEPOSITS
	LAMBETH GROUP
	CHALK
	SPT 'N' VALUE
	WATERSTRIKE

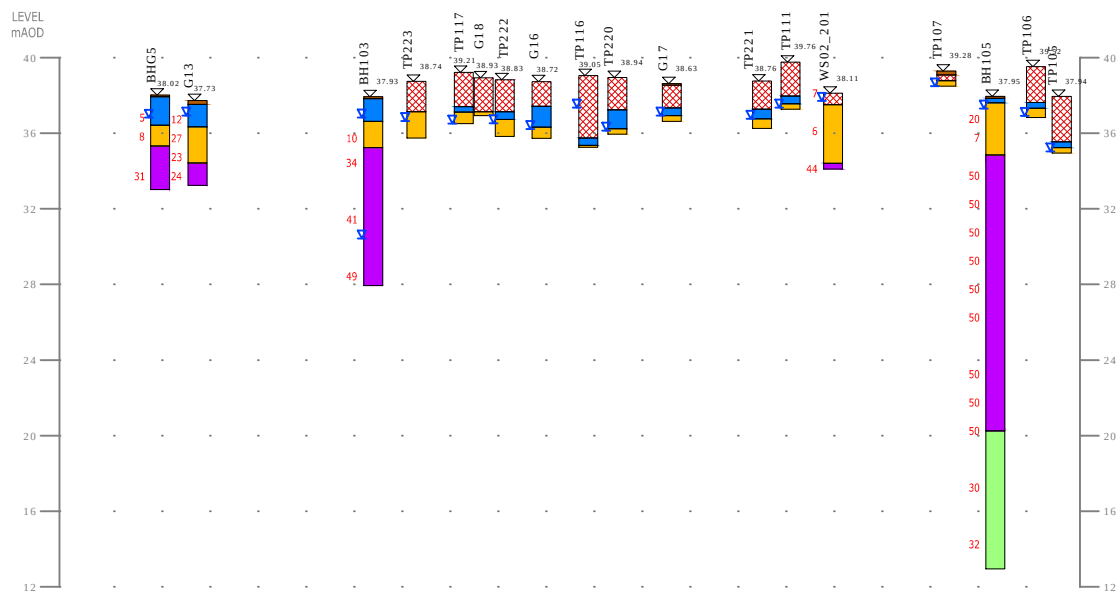


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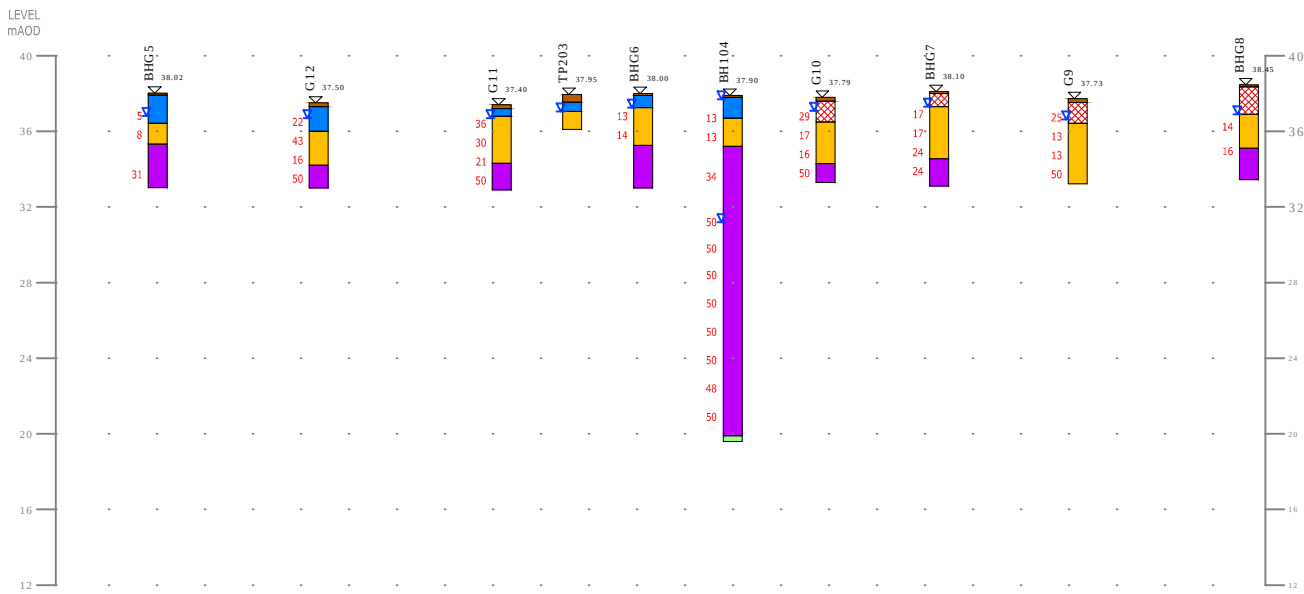
GREEN PARK VILLAGE READING

GEOLOGICAL SECTION B-B' & C-C'

Rev	Description	Date	By Chk	App
FOR INFORMATION				
Project No: 1620000492	Scale (@A3): AS SHOWN	Drawn: SKH	Date: FEB.16	
Drawing No: RAM-GDR-XX-DR-CG-003			Rev: I01	



SECTION D-D' 001
1: 1:2000(H), 1:400(V)



SECTION E-E' 001
1: 1:2000(H), 1:400(V)

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 - 6. FOR STRATA DETAILS REFER TO EXPLORATORY HOLE LOGS

KEY

TOPSOIL

MADE GROUND

ALLUVIUM

RIVER TERRACE DEPOSITS

LAMBETH GROUP

CHALK

'N'

 SPT 'N' VALUE

▽

 WATERSTRIKE

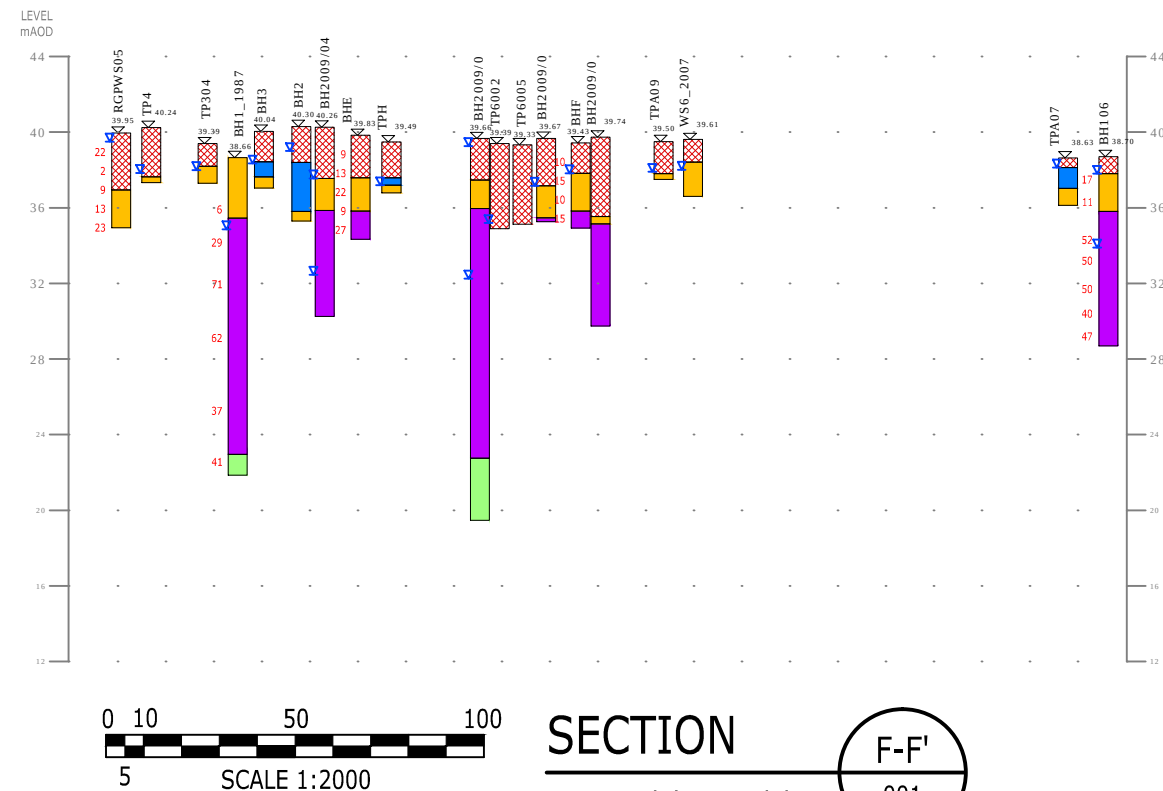


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GREEN PARK VILLAGE
READING

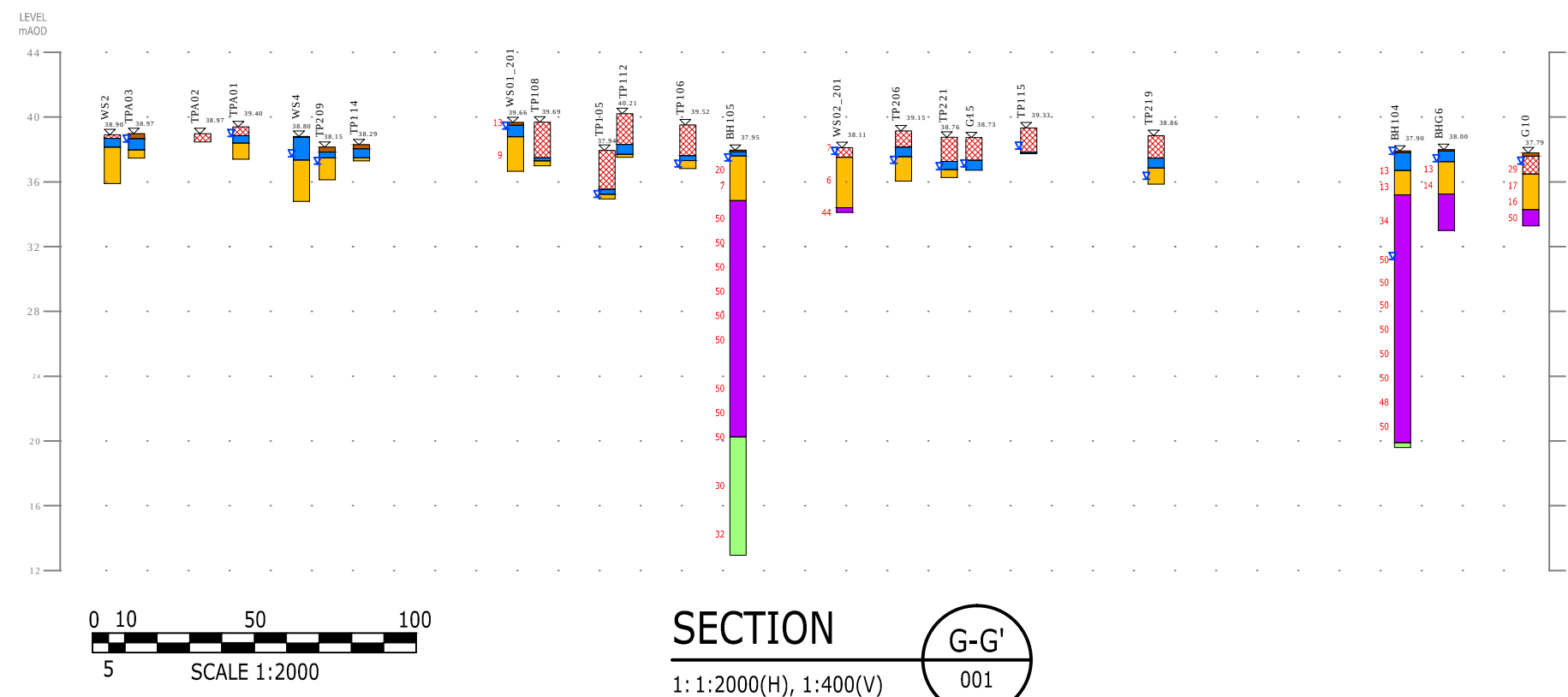
GEOLOGICAL SECTION D-D' & E-E'

Rev	Description	Date	By Chk	App
FOR INFORMATION				
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Drawing No: RAM-GDR-XX-DR-CG-004				Rev: I01



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- KEY
- TOPSOIL
 - MADE GROUND
 - ALLUVIUM
 - RIVER TERRACE DEPOSITS
 - LAMBETH GROUP
 - CHALK
 - 'N' SPT 'N' VALUE
 - WATERSTRIKE



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GREEN PARK VILLAGE
READING

GEOLOGICAL SECTION F-F' & G-G'

Rev	Description	Date	By Chk	App
FOR INFORMATION				
Project No: 1620000492		Scale (@A3): AS SHOWN	Drawn: SKH	Date: FEB.16
Drawing No: RAM-GDR-XX-DR-CG-005				Rev: I01

APPENDIX 1

LEGISLATIVE CONTEXT AND METHODOLOGIES

1. LEGISLATIVE CONTEXT

Environmental risks are assessed in accordance with Contaminated Land (England) (Amendment) Regulations 2012, Part IIA of the Environmental Protection Act 1990, and Environmental Protection Act 1990: Part 2A Contaminated Land Statutory Guidance, DEFRA 2012. Part IIA provides a statutory definition of contaminated land. To fall within this definition it is necessary that, as a result of the condition of the land, substances may be present on or under the land such that:

- (a) Significant harm is being caused or there is a significant possibility of such harm being caused; or
- (b) Significant pollution of controlled waters is being caused, or there is a significant possibility of such pollution being caused.

Risk from contamination is assessed by consideration of possible linkages between contaminant sources and potential receptors which could be harmed or polluted and the potential pathways between them. For a risk of pollution or environmental harm to occur as a result of ground contamination, all of the following elements must be present:

- A source - a substance that is capable of causing pollution or harm;
- A receptor - something which could be adversely affected by the contaminant; and
- A pathway - a route by which the contaminant can reach the receptor.

If one of these elements is absent there can be no significant risk. If all are present then the magnitude of the risk is a function of the magnitude and mobility of the source, the sensitivity of the receptor and the nature of the migration pathway.

The Environment Agency Contaminated Land Report CLR 11 Model Procedures for the Management of Land Contamination provides the technical framework for structured decision making about land contamination. CLR 11 advocates a phased approach to risk assessment comprising:

- Preliminary Risk Assessment (PRA) – desk study and qualitative assessment
- Generic Quantitative Risk Assessment (GQRA) – assessment of contaminant concentrations against generic assessment criteria.
- Detailed Quantitative Risk Assessment (DQRA) – detailed site specific risk assessment and development of site-specific assessment criteria.

Each of these phases follows the same basic steps but adds site specific details and further certainty into the assessment as the stages progress. The basic steps are:

- Hazard identification and hazard assessment – development or refinement of the source-pathway-receptor conceptual model, and identification of potential pollutant linkages.
- Risk Estimation – qualitative risk estimation predicting magnitude and probability of potential consequences that may arise as a result of a hazard.
- Risk Evaluation – deciding whether a risk is unacceptable.

2. RISK ESTIMATION

An assessment of environmental risks is made for each potential pollutant linkage identified.

Risk estimation has been completed in accordance with the guidance provided in:

- NHBC and Environment Agency 2008. Guidance for the Safe Development of Housing on Land Affected by Contamination. R&D Publication 66: 2008.

The following is taken directly from NHBC/EA 2008. The key to the classification is that the designation of risk is based upon the consideration of both:

- a) the magnitude of the potential consequence (*i.e.*, severity) [takes into account both the potential severity of the hazard and the sensitivity of the receptor];
- b) the magnitude of probability (*i.e.*, likelihood) [takes into account both the presence of the hazard and receptor and the integrity of the pathway].

Table 1: Classification of Consequence (after NHBC/EA 2008)

Category	Definition
Severe	Highly elevated concentrations likely to result in "significant harm" to human health as defined by the EPA 1990, Part 2A, if exposure occurs. Equivalent to EA Category 1 pollution incident including persistent and/or extensive effects on water quality; leading to closure of a potable abstraction point; major impact on amenity value or major damage to agriculture or commerce. Major damage to aquatic or other ecosystems, which is likely to result in a substantial adverse change in its functioning or harm to a species of special interest that endangers the long-term maintenance of the population. Catastrophic damage to crops, buildings or property.
Medium	Elevated concentrations which could result in "significant harm" to human health as defined by the EPA 1990, Part 2A if exposure occurs. Equivalent to EA Category 2 pollution incident including significant effect on water quality; notification required to abstractors; reduction in amenity value or significant damage to agriculture or commerce. Significant damage to aquatic or other ecosystems, which may result in a substantial adverse change in its functioning or harm to a species of special interest that may endanger the long-term maintenance of the population. Significant damage to crops, buildings or property.
Mild	Exposure to human health unlikely to lead to "significant harm". Equivalent to EA Category 3 pollution incident including minimal or short lived effect on water quality; marginal effect on amenity value, agriculture or commerce. Minor or short lived damage to aquatic or other ecosystems, which is unlikely to result in a substantial adverse change in its functioning or harm to a species of special interest that would endanger the long-term maintenance of the population. Minor damage to crops, buildings or property.
Minor	No measurable effect on humans. Equivalent to insubstantial pollution incident with no observed effect on water quality or ecosystems. Repairable effects of damage to buildings, structures and services.

* For these purposes, disease is to be taken to mean an unhealthy condition of the body or a part of it and can include, for example, cancer, liver dysfunction or extensive skin ailments. Mental dysfunction is included only insofar as it is attributable to the effects of a pollutant on the body of the person concerned.

The likelihood of an event (probability) takes into account both the presence of the hazard and target and the integrity of the pathway and has been assessed based on the categories given below.

Table 2: Classification of Probability (after NHBC/EA 2008)

Category	Definition
High Likelihood	There is pollutant linkage and an event would appear very likely in the short-term and almost inevitable over the long-term, or there is evidence at the receptor of harm or pollution.
Likely	There is pollutant linkage and all the elements are present and in the right place which means that it is probable that an event will occur. Circumstances are such that an event is not inevitable, but possible in the short-term and likely over the long-term.
Low Likelihood	There is pollutant linkage and circumstances are possible under which an event could occur. However, it is by no means certain that even over a long period such an event would take place, and is less likely in the shorter term.
Unlikely	There is pollutant linkage but circumstances are such that it is improbable that an event would occur even in the very long-term.

The potential severity of the risk and the probability of the risk occurring have been combined in accordance with the following matrix in order to give a level of risk for each potential hazard.

Table 3: The Classification of Risk (after NHBC/EA 2008)

		Consequence			
		Severe	Medium	Mild	Minor
Probability	High Likelihood	Very high	High	Moderate	Low
	Likely	High	Moderate	Moderate/ Low	Low
	Low Likelihood	Moderate	Moderate/ Low	Low	Very low
	Unlikely	Moderate/ Low	Low	Very low	Very low

Very high risk

There is a high probability that severe harm could arise to a designated receptor from an identified hazard at the site without remediation action OR there is evidence that severe harm to a designated receptor is already occurring. Realisation of that risk is likely to present a substantial liability to be site owner/or occupier. Investigation is required as a matter of urgency and remediation works likely to follow in the short-term.

High risk

Harm is likely to arise to a designated receptor from an identified hazard at the site without remediation action. Realisation of the risk is likely to present a substantial liability to the site owner/or occupier. Investigation is required as a matter of urgency to clarify the risk. Remediation works may be necessary in the short-term and are likely over the longer term.

Moderate risk

It is possible that harm could arise to a designated receptor from an identified hazard. However, it is either relatively unlikely that any such harm would be severe, and if any harm were to occur it is more likely, that the harm would be relatively mild. Further investigative work is normally required to clarify the risk and to determine the potential liability to site owner/occupier. Some remediation works may be required in the longer term.

Low risk

It is possible that harm could arise to a designated receptor from identified hazard, but it is likely at worst, that this harm if realised would normally be mild. It is unlikely that the site owner/or occupier would face substantial liabilities from such a risk. Further investigative work (which is likely to be limited) to clarify the risk may be required. Any subsequent remediation works are likely to be relatively limited.

Very low risk

It is a low possibility that harm could arise to a designated receptor, but it is likely at worst, that this harm if realised would normally be mild or minor.

No potential risk

There is no potential risk if no pollution linkage has been established.

3. GQRA METHODOLOGIES

In order to assess the significance of the chemical concentrations recorded, generic assessment criteria (GAC) must be selected. The GAC are screening concentrations which are used initially for direct comparison to the measured site concentrations.

The GAC are defined based on the critical receptors identified at the site. Receptors are considered in relation to:

- Human health receptors (*e.g.*, site users);
- The water environment (*e.g.*, groundwater and surface water).

Potential risks to human health are considered primarily using measured concentrations of chemicals in soil. Potential risks to the water environment are considered primarily using soil leachate and groundwater concentrations as indicative of the potentially mobile fraction of any soil impact.

Additional receptors may be relevant dependent on the site *e.g.*, flora/fauna, water supply pipes, buried concrete.

3.1. Human Health Assessment

3.1.1. Initial Screening Assessment

The GAC adopted for assessment of soils in relation to Human Health follow the hierarchy listed below:

- C4SLs (Category 4 Screening Levels) published by DEFRA 2014. The C4SL guidance is an update on previous DEFRA guidance with the main changes being a few alterations to human health exposure assumptions and use of 'low' risk toxicological inputs instead of the previously used 'minimal' risk inputs. C4SLs have only been generated for 6 compounds typically only at a soil organic matter content of 6%. Other guidance is therefore required.
- LQM/CIEH, 2014 S4ULs (Suitable for Use Levels). These are an update on the previous LQM/CIEH 2009 guidance, and keep the existing 'minimal' risk toxicological values alongside the DEFRA 2014 updated exposure parameters.
- EIC/AGS/CL:AIRE Dec 2009. The Soil Generic Assessment Criteria for Human Health Risk Assessment.
- Ramboll in-house screening criteria (derived in accordance with the published CLEA framework) are used if no published guideline value is available.

Soil Guideline Values (EA/DEFRA, 2009) may also be referred to if relevant.

Contaminant concentrations below the adopted GAC are not considered to present a significant risk to identified receptors and therefore are not considered to warrant further study. Contaminants which are recorded at concentrations above their respective GAC are considered to present a potential risk to identified receptors and resultantly these determinants are subject to further assessment.

3.1.2. Contaminant Distribution Assessment

Concentrations above the GAC are considered further in relation to vertical and lateral distribution across the site and through statistical analysis, where appropriate. This analysis is used to define 'averaging areas' within which contamination concentrations and distribution are considered likely to be similar.

For each averaging area, where appropriate, statistical analysis is then used to calculate a 'representative' concentration for each contaminant within that area and identify

possible outliers of the underlying distribution of contaminant concentrations. This analysis is completed in accordance with CIEH 2008 guidance.

The initial statistical tests are used to calculate the 95% probability that the true population mean falls below the critical concentration (GAC). In practise, this involves comparing the 95th Upper Confidence Limit of the true population mean with the GAC. The Maximum Value test is then used to identify whether the maximum concentration is likely to lie outside of the assumed distribution trend and as such would represent an outlier of the general population of data across the site. Outliers above the GAC may represent localised contaminant hotspots and require further consideration.

Constituent non-detects are conservatively assigned a value equal to the reported analytical laboratory limit of detection. Any identified true outliers are excluded from the datasets used in calculation of the 95%UCL value.

3.2. Assessment for the Water Environment

Assessment of risks to water resources is completed in general accordance with guidance provided in the Environment Agency 2013, Groundwater Protection Principles and Practice (GP3).

Generic assessment criteria for waters must be selected to assess potential risks to the identified environmental receptors. There are numerous UK and European guidelines for waters based on the site situation and different receptors.

For the majority of site situations, it is considered that use of UK drinking water standards (for non-hazardous substances) and minimum reporting values (for hazardous substances) will be most appropriate for assessment of risks to groundwater resources; and use of environmental quality standards for freshwater or marine waters will be most appropriate for assessment of risks to the surface water environment.

Water and leachate data may also be compared to e.g. bathing water standards etc. where this pollutant linkage may be present.

All water quality standards are sourced from the EA Chemical Standards Database online resource where possible.

4. GROUND GAS RISK ASSESSMENT

Ground gas risk is characterised using guidance provided in the following:

- CIRIA C665, 2007. Assessing risks posed by hazardous ground gases to buildings. (Supersedes CIRIA 659).
- NHBC / RSK, 2007. Guidance on evaluation of development proposals on sites where methane and carbon dioxide are present. Report Ed 4.
- BS8485: 2015. Code of practice for the design of protective measures for methane and carbon dioxide ground gases for new buildings.
- BS8576:2013. Guidance on investigations for ground gas – Permanent gases and Volatile Organic Compounds (VOCs)

The risk posed by a gas regime is assessed initially by calculating a Gas Screening Value using a combination of the gas flow rate and recorded concentrations of carbon dioxide and methane. This Gas Screening Value is then used in combination with the maximum recorded gas concentrations to determine the site's Characteristic Situation (CIRIA 665 – all site uses except low rise residential) or Traffic Light Classification (NHBC/RSK 2007 low rise residential sites only). Table A below outlines the method for defining the Characteristic Situation as detailed in CIRIA 665 and Table B outlines the method for defining the Traffic Light classification as detailed in NHBC/RSK 2007.

Table A: Proposed method for classifying gassing sites (after CIRIA C665 2007)

Characteristic Situation	Risk classification	Gas screening value of CH ₄ or CO ₂ (l/hr) ^a	Additional limiting factors	Typical source of generation
1	Very low risk	<0.07	Typically methane ≤ 1% and/or carbon dioxide ≤ 5%. Otherwise consider increase to Situation 2	Natural soils with low organic content. "Typical" Made Ground
2	Low risk	<0.7	Borehole air flow rate not to exceed 70l/hr. Otherwise consider increase to Characteristic Situation 3	Natural soil, high peat/organic content. "Typical" Made Ground
3	Moderate risk	<3.5	-	Old landfill, inert waste, mineworking flooded
4	Moderate to high risk	<15	Quantitative risk assessment required to evaluate scope of protective measures	Mineworking -susceptible to flooding, completed landfill, inert waste (WMP 26B criteria)
5	High risk	<70	-	Mineworking unflooded inactive with shallow workings near surface
6	Very high risk	>70	-	Recent landfill site

^a Gas screening value = gas concentration (%) x measured borehole flow rate (l/hr)

Table B: Proposed method for classifying gassing sites (after NHBC/RSK 2007)

Traffic Light	Methane ¹		Carbon Dioxide ¹	
	Typical Maximum Concentration ⁵ (%v/v)	Gas Screening Value (GSV) ^{2,4,6} litres per hour	Typical Maximum Concentration ⁵ (%v/v)	Gas Screening Value (GSV) ^{2,3,4,5} litres per hour
Green				
Amber 1	1	0.16	5	0.78
Amber 2	5	0.63	10	1.56
Red	20	1.56	30	3.13

The CIRIA, NHBC and BS8485 guidance documents are then used to determine requirements for gas protection measures based on the site classification.

APPENDIX 2

RAMBOLL GAC

Generic Assessment Criteria for soils - to be protective of human health v10.3 Sep-15									
Determinand	Units	Soil Organic Matter	Residential	Residential without homegrown produce	Allotments	Commercial / Industrial	Public Open Space 1 Green space close to housing	Public Open Space 2 Green space far enough from housing that there will be negligible tracking back of soil	Origin of Value
Inorganics									
Arsenic	mg/kg	-	37	40	49	640	79	168	C4SL (DEFRA 2014)
Arsenic	mg/kg	-	37	40	43	640	79	170	LQM/CIEH 2014
Beryllium	mg/kg	-	1.7	1.7	35	12	2.2	63	LQM/CIEH 2014
Boron	mg/kg	-	290	11000	45	240000	21000	46000	LQM/CIEH 2014
Cadmium	mg/kg	-	26	149	4.9	410	220	880	C4SL (DEFRA 2014)
Cadmium	mg/kg	-	11	85	1.9	190	120	532	LQM/CIEH 2014
Cadmium	mg/kg	-	10	85	1.8	230			SGV 2009
Chromium (III)	mg/kg	-	910	910	18000	8600	1500	33000	LQM/CIEH 2014
Chromium (VI)	mg/kg	-	21	21	170	49	23	250	C4SL (DEFRA 2014)
Chromium (VI)	mg/kg	-	6	6	1.8	33	7.7	220	LQM/CIEH 2014
Copper	mg/kg	-	2400	7100	520	68000	12000	44000	LQM/CIEH 2014
Lead	mg/kg	-	200	310	80	2330	630	1300	C4SL (DEFRA 2014)
Mercury - elemental	mg/kg	1% SOM	0.17	0.17	130 (4.3*)	18 (4.3*)			Calculated with CLEA v1.06
	mg/kg	2.5% SOM	0.42	0.42	200 (11*)	46 (11*)			Calculated with CLEA v1.06
	mg/kg	6% SOM	1	1	320 (26*) ^[d]	110 (26*) ^[d]			SGV 2009
	mg/kg	6% SOM	1.2	1.2	21	58 (25.8*)	16	30 (25.8*)	LQM/CIEH 2014
Mercury - inorganic	mg/kg	-	170	240	80	3600			SGV 2009
	mg/kg	-	40	56	19	1100	120	240	LQM/CIEH 2014
Mercury - methyl	mg/kg	1% SOM	7.4	8.4	8	370 (73*)			Calculated with CLEA v1.06
	mg/kg	2.5% SOM	9.6	11	8	390			Calculated with CLEA v1.06
	mg/kg	6% SOM	11	14	8	410			SGV 2009
	mg/kg	6% SOM	11	15	6	320	40	68	LQM/CIEH 2014
Nickel	mg/kg	-	130	180	53	980	230	800	LQM/CIEH 2015
	mg/kg	-	130	130	230	1800			SGV 2009
Selenium	mg/kg	-	250	430	88	12000	1100	1800	LQM/CIEH 2014
	mg/kg	-	350	600	120	13000			SGV 2009
Vanadium	mg/kg	-	410	1200	91	9000	2000	5000	LQM/CIEH 2014
Zinc	mg/kg	-	3700	40000	620	730000	81000	170000	LQM/CIEH 2014
Free cyanide	mg/kg	-	49	49	49	49			Ramboll UK
Organics									
Phenol	mg/kg	1% SOM	280	750	66	760 (31000 ^[d])	760 (11000 ^[d])	760 (8600 ^[d])	LQM/CIEH 2014
	mg/kg	2.5% SOM	550	1300	140	1500 (35000 ^[d])	1500 (11000 ^[d])	1500 (9700 ^[d])	LQM/CIEH 2014
	mg/kg	6% SOM	1100	2300	280	3200 (37000 ^[d])	3200 (11000 ^[d])	3200 (11000 ^[d])	LQM/CIEH 2014
Dioxins (sum of PCDDs, PCDFs, and dioxin- like PCBs) ^[2]	µg/kg	-	8	8	8	240			SGV 2009
PAH Congeners									
Acenaphthene	mg/kg	1% SOM	210	3000 (57*)	34	84000 (57*)	15000	29000	LQM/CIEH 2014
	mg/kg	2.5% SOM	510	4700 (141*)	85	97000 (141)	15000	30000	LQM/CIEH 2014
	mg/kg	6% SOM	1100	6000 (336*)	200	100000	15000	30000	LQM/CIEH 2014
Acenaphthylene	mg/kg	1% SOM	170	2900 (86.1*)	28	83000 (86.1*)	15000	29000	LQM/CIEH 2014
	mg/kg	2.5% SOM	420	4600 (212*)	69	97000 (212*)	15000	30000	LQM/CIEH 2014
	mg/kg	6% SOM	920	6000 (506*)	160	100000	15000	30000	LQM/CIEH 2014
Anthracene	mg/kg	1% SOM	2400	31000 (1.17*)	380	520000	74000	150000	LQM/CIEH 2014
	mg/kg	2.5% SOM	5400	35000	950	540000	74000	150000	LQM/CIEH 2014
	mg/kg	6% SOM	11000	37000	2200	540000	74000	150000	LQM/CIEH 2014
Benzo (a) anthracene ^[1]	mg/kg	1% SOM	7.2	11	2.9	170	29	49	LQM/CIEH 2014
	mg/kg	2.5% SOM	11	14	6.5	170	29	55	LQM/CIEH 2014
	mg/kg	6% SOM	13	15	13	180	29	62	LQM/CIEH 2014
Benzo (a) pyrene ^[1]	mg/kg	1% SOM							
	mg/kg	2.5% SOM							
	mg/kg	6% SOM	5	5.3	5.7	76	10	21	C4SL (DEFRA 2014)
Coal Tar (Benzo (a) pyrene as surrogate marker) ^[1]	mg/kg	1% SOM	0.79	1.2	0.32	15	2.2	4.4	LQM/CIEH 2014
	mg/kg	2.5% SOM	0.98	1.2	0.67	15	2.2	4.7	LQM/CIEH 2014
	mg/kg	6% SOM	1.1	1.2	1.2	15	2.2	4.8	LQM/CIEH 2014
Benzo (a) pyrene ^[1]	mg/kg	1% SOM	2.2	3.2	0.97	35	5.7	11	LQM/CIEH 2014
	mg/kg	2.5% SOM	2.7	3.2	2	35	5.7	12	LQM/CIEH 2014
	mg/kg	6% SOM	3	3.2	3.5	36	5.5	13	LQM/CIEH 2014
Benzo (b) fluoranthene ^[1]	mg/kg	1% SOM	2.6	3.9	0.99	44	7.1	13	LQM/CIEH 2014
	mg/kg	2.5% SOM	3.3	4	2.1	44	7.2	15	LQM/CIEH 2014
	mg/kg	6% SOM	3.7	4	3.9	45	7.2	16	LQM/CIEH 2014
Benzo (ghi) perylene ^[1]	mg/kg	1% SOM	320	360	290	3900	640	1400	LQM/CIEH 2014
	mg/kg	2.5% SOM	340	360	470	4000	640	1500	LQM/CIEH 2014
	mg/kg	6% SOM	350	360	640	4000	640	1600	LQM/CIEH 2014
Benzo (k) fluoranthene ^[1]	mg/kg	1% SOM	77	110	37	1200	190	370	LQM/CIEH 2014
	mg/kg	2.5% SOM	93	110	75	1200	190	410	LQM/CIEH 2014
	mg/kg	6% SOM	100	110	130	1200	190	440	LQM/CIEH 2014
Chrysene ^[1]	mg/kg	1% SOM	15	30	4.1	350	57	93	LQM/CIEH 2014
	mg/kg	2.5% SOM	22	31	9.4	350	57	110	LQM/CIEH 2014
	mg/kg	6% SOM	27	32	19	350	57	120	LQM/CIEH 2014
Dibenzo(a,h)anthracene ^[1]	mg/kg	1% SOM	0.24	0.31	0.14	3.5	0.57	1.1	LQM/CIEH 2014
	mg/kg	2.5% SOM	0.28	0.32	0.27	3.6	0.57	1.3	LQM/CIEH 2014
	mg/kg	6% SOM	0.3	0.32	0.43	3.6	0.58	1.4	LQM/CIEH 2014
Fluoranthene	mg/kg	1% SOM	280	1500	52	23000	3100	6300	LQM/CIEH 2014
	mg/kg	2.5% SOM	560	1600	130	23000	3100	6300	LQM/CIEH 2014
	mg/kg	6% SOM	890	1600	290	23000	3100	6400	LQM/CIEH 2014
Fluorene	mg/kg	1% SOM	170	2800 (30.9*)	27	63000 (30.9*)	9900	20000	LQM/CIEH 2014
	mg/kg	2.5% SOM	400	3800 (76.5*)	67	68000	9900	20000	LQM/CIEH 2014
	mg/kg	6% SOM	860	4500 (183*)	160	71000	9900	20000	LQM/CIEH 2014
Indeno (123-cd) pyrene ^[1]	mg/kg	1% SOM	27	45	9.5	500	82	150	LQM/CIEH 2014
	mg/kg	2.5% SOM	36	46	21	510	82	170	LQM/CIEH 2014
	mg/kg	6% SOM	41	46	39	510	82	180	LQM/CIEH 2014
Naphthalene	mg/kg	1% SOM	2.3	2.3	4.1	190 (76.4*)	4900	1200 (76.4*)	LQM/CIEH 2014
	mg/kg	2.5% SOM	5.6	5.6	10	460 (183*)	4900	1900 (183)	LQM/CIEH 2014
	mg/kg	6% SOM	13	13	24	1100 (432*)	4900	3000	LQM/CIEH 2014
Phenanthrene	mg/kg	1% SOM	95	1300 (36*)	15	22000	3100	6200	LQM/CIEH 2014
	mg/kg	2.5% SOM	220	1500	38	22000	3100	6200	LQM/CIEH 2014
	mg/kg	6% SOM	440	1500	90	23000	3100	6300	LQM/CIEH 2014
Pyrene	mg/kg	1% SOM	620	3700	110	54000	7400	15000	LQM/CIEH 2014
	mg/kg	2.5% SOM	1200	3800	270	54000	7400	15000	LQM/CIEH 2014
	mg/kg	6% SOM	2000	3800	620	54000	7400	15000	LQM/CIEH 2014
BTEX									
Benzene	mg/kg	1% SOM	0.2	0.89	0.039	27	140	190	provisional C4SL (CL:AIRE dec2013)
	mg/kg	2.5% SOM							
	mg/kg	6% SOM	0.87	3.3	0.18	98	140	230	C4SL (DEFRA 2014)
Benzene	mg/kg	1% SOM	0.087	0.38	0.017	27	72	90	LQM/CIEH 2014
	mg/kg	2.5% SOM	0.17	0.7	0.034	47	72	100	LQM/CIEH 2014
	mg/kg	6% SOM	0.37	1.4	0.075	90	73	110	LQM/CIEH 2014
Ethylbenzene	mg/kg	1% SOM	47	83	16	5700 (518*)	24000	17000 (518*)	LQM/CIEH 2014
	mg/kg	2.5% SOM	110	190	39	13000 (1220*)	24000	22000 (1220*)	LQM/CIEH 2014
	mg/kg	6% SOM	260	440	91	27000 (2840*)	25000	27000 (2840*)	LQM/CIEH 2014
Toluene	mg/kg	1% SOM	130	880 (869*)	22	56000 (869*)	56000	87000 (869*)	LQM/CIEH 2014
	mg/kg	2.5% SOM	290	1900	51	110000 (1920*)	56000	95000 (1920*)	LQM/CIEH 2014
	mg/kg	6% SOM	660	3900	120	180000 (4360*)	56000	100000 (4360*)	LQM/CIEH 2014
Xylene -m	mg/kg	1% SOM	59	82	31	6200 (625*)	41000	17000 (625*)	LQM/CIEH 2014
	mg/kg	2.5% SOM	140	190	74	14000 (1470*)	42000	24000 (1470*)	LQM/CIEH 2014
	mg/kg	6% SOM	320	450	170	31000 (3460*)	43000	32000 (3460)	LQM/CIEH 2014
Xylene -o	mg/kg	1% SOM	60	88	28	6600 (478*)	41000	17000 (478*)	LQM/CIEH 2014
	mg/kg	2.5% SOM	140	210	67	15000 (1120*)	42000	24000 (1120*)	LQM/CIEH 2014
	mg/kg	6% SOM	330	480	160	33000 (2620*)	43000	33000 (2620*)	LQM/CIEH 2014
Xylene -p	mg/kg	1% SOM	56	79	29	5900 (576*)	41000	17000 (576*)	LQM/CIEH 2014
	mg/kg	2.5% SOM	130	180	69	14000 (1350*)	42000	23000 (1350*)	LQM/CIEH 2014
	mg/kg	6% SOM	310	430	160	30000 (3170*)	43000	31000 (3170*)	LQM/CIEH 2014

6% SOM = foc of 0.035

		Groundwater		Surface Water	
		Drinking Water Resources		General Environmental Quality	
Determinand	Units	Discharge of Hazardous Substances ^[1]	Discharge of Non-Hazardous Substances ^[2]	Fresh Water EQS	Marine Water EQS
		Minimum Reporting Values	Resource Protection Values		
Ammonium (NH ₄)	µg/l	-	500(MAC)	300-600 (Dependent on alkalinity & altitude)	21 (AA)
Anthracene	µg/l	-	-	0.1 (AA) 0.4 (MAC)	0.1 (AA) 0.4 (MAC)
Antimony	µg/l	-	5	-	-
Arsenic	µg/l	-	10	50 (AA)	25 (AA)
Barium	µg/l	-	700	-	-
Benzene	µg/l	1	1	10 (AA) 50 (MAC)	8 (AA) 50 (MAC)
Benzo-a-pyrene	µg/l	-	0.01	0.05 (AA) 0.1 (MAC)	0.05 (AA) 0.1 (MAC)
Boron	µg/l	-	1000	2000 (AA)	7000 (AA)
Cadmium	µg/l	0.1 (<1)	5	Hardness	EQS
				<40mg CaCO3/l	≤0.08 (AA) ≤0.45 (MAC)
				40 to <50mg CaCO3/l	0.08 (AA) 0.45 (MAC)
				50 to <100mg CaCO3/l	0.09 (AA) 0.6 (MAC)
				100 to <200mg CaCO3/l	0.15 (AA) 0.9 (MAC)
				≤200mg CaCO3/l	0.25 (AA) 1.5 (MAC)
Chloride (Water Soluble)	µg/l	-	250000	250000 (AA)	-
Chlorine	µg/l	-	NU (250000)	2 (AA) 5 (95%-ile)	10 (AA)
Chromium	µg/l	-	50	-	-
Chromium III	µg/l	-	-	4.7 (AA) 32 (95%-ile)	-
Chromium VI	µg/l	-	-	3.4 (AA)	0.6 (AA) 32 (95%-ile)
Copper ^[3]	µg/l	-	2000	Hardness ^[3]	EQS
				0-50mg CaCO3/l	1 (AA)
				50-100mg CaCO3/l	6 (AA)
				100-250mg CaCO3/l	10 (AA)
				>250mg CaCO3/l	28 (AA)
Cyanide (as free cyanide)	µg/l	-	50	1 (AA) 5 (95%-ile)	1 (AA) 5 (95%-ile)
1,2-dichloroethane (total)	µg/l	1	5 ^[4]	10 (AA)	10 (AA)
Electrical Conductivity	µS/cm	-	2500	-	-
Ethylbenzene	µg/l	-	300	20 (AA) 200 (MAC)	20 (AA) 200 (MAC)
Fluoranthene	µg/l	-	-	0.1 (AA) 1 (MAC)	0.1 (AA) 1 (MAC)
Iron (dissolved)	µg/l	-	200	1000 (AA)	1000 (AA)
Lead (Dissolved)	µg/l	-	25	7.2 (AA)	7.2 (AA)
Manganese (Dissolved)	µg/l	-	50	30 (AA) 300 (MAC)	-
Mercury	µg/l	0.01 (<0.1)	1	0.05 (AA) 0.07 (MAC)	0.05 (AA) 0.07 (MAC)
Methylphenols (cresols)	µg/l	-	-	100 (AA) 300 (MAC)	100 (AA) 300 (MAC)
Naphthalene	µg/l	-	-	2.4 (AA)	1.2 (AA)
Nickel (Dissolved)	µg/l	-	20	20 (AA)	20 (AA)
Nitrites (NO ₂)	µg/l	-	500	-	-
PAH: (Sum of: Benzo(b) fluoranthene Benzo(k)fluoranthene Benzo(ghi)perylene Indeno(1,2,3-cd)pyrene)	µg/l	-	0.1	-	-
PAH: (Sum of Benzo(b)fluoranthene & Benzo(k)fluoranthene)	µg/l	-	-	0.03 (AA)	0.03 (AA)
PAH: (Sum of Benzo(ghi)perylene & Indeno(123-cd)pyrene)	µg/l	-	-	0.002 (AA)	0.002 (AA)
PCBs	µg/l	0.001 (individual congeners)	0.5		
pH		-	<6.5, >10	<6, >9	<7, >9
Phenol	µg/l	-	0.5	7.7 (AA) 46 (95%-ile)	7.7 (AA) 46 (95%-ile)
Selenium	µg/l	-	10	-	-
Sulphate	µg/l	-	-	400000 (AA)	-
Tetrachloroethylene (PCE)	µg/l	0.1	-	10 (AA)	10 (AA)
Tetrachloroethene + Trichloroethene (PCE+TCE)	µg/l	-	10	-	-
Trichloroethene (TCE)	µg/l	0.1	-	10 (AA)	10 (AA)
Toluene	µg/l	4	700	50 (AA) 380 (95%-ile)	40 (AA) 370 (95%-ile)
TPH	µg/l	-	10	-	-
Vanadium (Total)	µg/l	-	-	Hardness	EQS
				0-200mg CaCO3/l	20 (AA)
				>200mg CaCO3/l	60 (AA)
Vinyl Chloride (VC)	µg/l	-	0.5	-	-
Xylenes	µg/l	3	500	30 (AA)	30 (AA)
Zinc	µg/l	-	-	Hardness	EQS
				0-50mg CaCO3/l	8 (AA)
				50-100mg CaCO3/l	50 (AA)
				100-500mg CaCO3/l	75 (AA)
				>500mg CaCO3/l	125 (AA)

Notes

Shortlist of common substances listed, see references below for additional substances

AA = Annual Average

MAC = Maximum Allowable Concentration

^[1] **MRV** (Minimum Reporting Values) for **active** discharge of Hazardous Substances only (e.g. soakaways or active landfill). Alternative MRV in brackets may be used if MRV cannot be reasonably acheived by current lab detection limits. (ref WAT-PS-10-01, SEPA March 2010)

^[2] **RPV** (Resource Protection Value) - standard to give general protection to the groundwater resource for human consumption. RPVs heirarchy: UK and EC Drinking Water Standards, WHO Drinking Water Quality Guidelines, US EPA National Primary Drinking Water Regulations.

Hazardous Substances (includes all List 1 Substances)

^[3] Hardness categories for copper differ in SEPA guidance. 0-10mg CaCO3/l: 1ug/l. 10-50mg CaCO3/l: 6ug/l. 50-100mg CaCO3/l: 10ug/l. >100mg CaCO3/l: 28ug/l.

^[4] SEPA RPV for 1,2, dichloroethane: 3ug/l.

Concise summary framework for assessment of risks to waters detailed in WAT-PS-10-01, SEPA March 2010

References

EA website Chemical Standards Database: <http://evidence.environment-agency.gov.uk/ChemicalStandards/home.aspx>

EA chemical standards database references numerous source documents including (most relevant for this GAC sheet):

- Water Supply (Water Quality) Regulations 2000: UK Government drinking water standards applicable at consumers tap
- The River Basin Districts Typology, Standards and Groundwater Threshold Values (Water Framework Directive) (England and Wales) Directions 2010
- (Dangerous Substances Directive) - List II substances
- Council Directive on pollution caused by certain dangerous substances discharged into the aquatic environment of the Community (Dangerous Substances Directive) - List II substances
- WHO guidelines for drinking water quality

Scotland guidance in SEPA documents:

- Assigning Groundwater Assessment Criteria for Pollutant Inputs (WAT-PS-10-01), SEPA, March 2010
- EQS (Environmental Quality Standards) Supporting Guidance (WAT-SG-53) SEPA
- http://www.sepa.org.uk/water/water_regulation/guidance/pollution_control.aspx

Other water quality standards to be used where appropriate eg Bathing Water Standards