



Wates Construction Limited

Yapton Road, Barnham

Preliminary Geoenvironmental and
Geotechnical Assessment



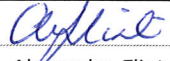


TWEEDIE EVANS CONSULTING

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Preliminary Geoenvironmental and Geotechnical Assessment

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Tweedie Evans Consulting Limited
The Old Chapel
35a Southover
Wells
Somerset
BA5 1UH
Tel: 01749 677760
Email: info@tecon.co.uk

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1 INTRODUCTION**1.1 Terms of Reference**

- 1.1.1 Tweedie Evans Consulting Ltd (TEC) has been appointed by Wates Construction Limited to undertake a preliminary geoenvironmental and geotechnical assessment of Barnham Road, Yapton. All works were undertaken in accordance with our proposal letter dated 07 March 2018 and referenced 1801024.001_003.bidlet.

1.2 Background

- 1.2.1 The site is an area of land, formerly understood to have been occupied by a garden nursery (Angel's Nursery), located off Yapton Road, to the south-east of Barnham (Figure 1). The site covers an area off approximately 3.46 hectares, with the centre located at approximate National Grid Reference 496260, 104030. The nearest postcode is PO22 0AY.
- 1.2.2 The proposed development is understood to comprise the construction of 95No. low rise residential units with associated parking and private gardens (Figure 2).
- 1.2.3 It is understood that a number of conditions have been outlined in associated with the site. Planning Permission (ref: BN/43/16PL) refers to the need to establish the sustainable drainage systems (SuDS) potential of the site (Condition 5 and 6), the potential for contamination and remediation strategy, if applicable (Condition 9) and verification upon the completion of the works, if applicable (Condition 10).
- 1.2.4 There have been a number of previous assessment undertaken at the site. The following reports are available on the Arun District Council planning portal, submitted as supporting documentation for the redevelopment of the site:
- Albury S.I Ltd – 'Report on a Desk Study at Angels Nursery, Yapton Road, Barnham, West Sussex, PO22 0AY'. Report Ref: 09/8848/90, dated November 2009. Prepared for West Sussex County Council;
 - WSP – 'Angel's Nursery Redevelopment Groundwater Assessment'. Project Number 00040420k, Revision 1, dated July 2014. Prepared for West Sussex County Council;
 - Geo-Environmental Services Limited – 'Ground Investigation Report – Angels Nursery, Yapton Road, Barnham'. Report Ref: GE10423-GIR-SEP15, Version: Final and dated September 2015. Prepared for Lovell Partnership Limited; and
 - Geo-Environmental Services Limited – 'Remediation Method Statement – Angels Nursery, Yapton Road, Barnham'. Report Ref: GE15163-RMS-DECP15, Version: 1.0 and dated September 2015. Prepared for Lovell Partnership Limited.
- 1.2.5 As these reports are public domain information, these have been reviewed as part of the current assessment. Where reviewed this information has been used in good faith although it should be noted that no reliance can be placed on the validity of this third-party information, unless noted, and no liability can or will be taken by TEC for the accuracy contained within this historical information.
- 1.2.6 The aim of these works is to provide information on geoenvironmental and engineering conditions and constraints associated with the site with regard to the proposed development.

1.3 Scope of Works

1.3.1 The scope of work undertaken as part of this report is presented below:

- Preliminary Risk Assessment. This phase of assessment involves development of an initial site conceptual model, based on desk study research, a site reconnaissance survey and review of previous reports, in order to establish whether or not there are potentially unacceptable risks.
- Generic Quantitative Risk Assessment. This phase of assessment involves refinement of the site conceptual model developed as part of the Preliminary Risk Assessment based on the findings of an intrusive investigation. Generic assessment criteria and assumptions, if appropriate, are used to evaluate potentially unacceptable risks. Should unacceptable risks be identified, a feasible remediation options appraisal is provided and/or a Detailed Quantitative Risk Assessment is recommended. The purpose of the Detailed Quantitative Risk Assessment is to further refine the conceptual model and use more detailed site specific information and criteria to determine whether there are unacceptable risks.
- Preliminary Geotechnical Assessment. General recommendations regarding likely engineering abnormalities are provided on the basis of the findings of an intrusive investigation, together with preliminary foundation design recommendations for the proposed development.

1.3.2 The above scope of work has been undertaken in accordance with current guidance such as CLR 11 'Model Procedures for the Management of Land Contamination' (Environment Agency, 2004), BS10175+A1 (2013) and, where appropriate NHBC and Eurocode 7.

1.3.3 The report is presented in the following format.

- Preliminary Risk Assessment:
Section 2 - Site Description
Section 3 - Site History
Section 4 - Environmental Setting
Section 5 - Outline Conceptual Model
- Generic Quantitative Risk Assessment:
Section 6 - Intrusive Investigation
Section 7 - Encountered Ground Conditions
Section 8 - Contamination Characterisation
Section 9 - Refined Conceptual Model
- Preliminary Geotechnical Assessment:
Section 10 - Ground Engineering
- Section 11 - Conclusions and Recommendations

2 SITE DESCRIPTION**2.1 Site Location**

- 2.1.1 The site is located within a predominantly residential area and is bounded by the following features (Table 2.1):

Table 2.1: Site Boundary Features

Direction from Site	Description
North	Barnham Community Hall, residential properties and Yapton Road.
East	Residential properties, caravan site and garden nurseries.
South	Open field and further garden nurseries.
West	Barnham Community Hall and recreation ground.

2.2 Land Use and Site Condition

- 2.2.1 A site reconnaissance survey was undertaken on 19th March 2018. A summary of the observations is presented below. Photographs taken during the site reconnaissance survey are presented in Appendix A.

Current Site Use

- 2.2.2 At the time of the site walkover, the site was not in use and was fenced off from the public. Evidence of previous structures was observed during the walkover, eg foundations (Photograph 7) and 2No. shallow ditches running approximately north-east to south-west across the site (Photograph 8).

Site Topography

- 2.2.3 The site was observed to be generally flat, with the exception of a spoil mound in the north-western part of the site (Photograph 4).

Hard and Soft Landscaping

- 2.2.4 With the exception of some concrete hardstanding, the site was observed to be generally lain to grass. In addition, several mature trees were noted on the site; however, at the time of the walkover, the majority were noted to have been felled.

Fuel Storage

- 2.2.5 Although information within the Albury S.I. Ltd reports indicates the presence of 9No above ground fuel storage tanks at the site, at the time of the site walkover, these had been removed and no visual or olfactory evidence was observed on the ground

Hazardous Chemicals and Waste Materials Storage

- 2.2.6 There was no evidence of the storage of hazardous chemicals or waste material onsite; however, the previous use as a plant nursery indicates that it is likely that localised storage of chemicals will have taken place.

Asbestos Containing Materials

- 2.2.7 There was no evidence of potentially asbestos containing materials onsite during the site walkover.

Site Drainage

- 2.2.8 Two shallow ditches were observed at the site, running through the site in an approximate north-east to south-west orientation (Photograph 8). Manholes were also observed on site, possibly associated with relict site drainage.

Evidence of Potential Contamination

- 2.2.9 There was no visual or olfactory evidence of gross contamination observed during the walkover.

General

- 2.2.10 Information was provided by the client, onsite, regarding a pressurised foul sewer that is understood to run along the southern boundary of the site.

3 SITE HISTORY**3.1 Introduction**

3.1.1 Details of the site history have been obtained through the review of historical Ordnance Survey (OS) mapping. The mapping reviewed is contained within Appendix B.

3.1.2 It is not the purpose of this section to provide a comprehensive account of development history, but only to detail those factors that are or could be relevant to the potentially contaminative history of the site and surrounds and the development of an outline site conceptual model.

3.2 Site History

3.2.1 The following represents a summary of potentially significant features recorded within the site area (Table 3.1).

Table 3.1: Site Features

Site Features	OS Dates
The site is shown to comprise undeveloped fields until 1938-1951 OS mapping, when a possible residential property and associated outbuildings are first recorded in the central site area.	1880 - 1967
A number of further buildings are shown on the site in the central and eastern area and a track is recorded to cross the site from east to west.	1967 - 1980
Further expansion of the site is shown with large structures recorded in the central and western areas and the site is identified as a nursery. A drain is recorded in the southern central site area on 2000 OS mapping.	1980 - 2006
The site is no longer recorded as a nursery and the majority of the previous buildings and structures are no longer recorded, with the exception of a couple of small buildings in the northern and central site area.	2018

3.3 Neighbouring History

3.3.1 The land uses within the immediate vicinity of the site have been considered. Based upon the reviewed map information the following potentially significant features have been identified (Table 3.2).

Table 3.2: Surrounding Features

Surrounding Features	OS Dates	Distance	Direction
Nurseries, With tanks from ~90m	1897	From ~10m	North, north-east and east
West Coast Railway Line	1880	~200m	North

4 ENVIRONMENTAL SETTING**4.1 Information Sources**

- 4.1.1 Environmental information for the site has been obtained through review of a Envirocheck® report for the site. This report provides extensive information, obtained from regulatory and commercial sources, regarding the environmental setting of the site. The Envirocheck® report has been included within Appendix C.

4.2 Geology and HydrogeologyGeology

- 4.2.1 The Envirocheck® report and published mapping indicates the following sequence at the site:

Table 4.1: Geological Setting

Geological Unit	Thickness	BGS Description
River Terrace Deposits (Undifferentiated)	Unknown	Sand and gravel, locally with lenses of silt, clay or peat.
London Clay Formation	Up to 150m	Comprises bioturbated or poorly laminated, blue-grey or grey-brown, slightly calcareous, silty to very silty clay, clayey silt and sometimes silt, with some layers of sandy clay.
Lambeth Group	Up to 40m	Vertically and laterally variable sequences mainly of clay, some silty or sandy, with some sands and gravels, minor limestones and lignites and occasional sandstone and conglomerate.

- 4.2.2 There are 2no. BGS borehole records within 250m of the site, as follows;
- SU90SE10 (approximately 90m east); records drift (unspecified thickness), London Clay and Reading beds to 185ft (~61mbgl), underlain by the Upper Chalk; and
 - SU90SE25 (approximately 250m south-east); records soil and made ground to 0.4mbgl, underlain by Brickearth of brown silty clay to 3.1m, underlain by the Upper Chalk to observed depths of 5.3mbgl (recorded as very chalky silt with chalk pebbles to 4.5m, becoming soft weather chalk).
- 4.2.3 Envirocheck® background soil chemistry on site is reported as the following;
- Arsenic – <15mg/kg
 - Cadmium - <1.8mg/kg
 - Chromium – 60-90mg/kg
 - Lead – 100-200mg/kg
 - Nickel – 15-30mg/kg
- 4.2.4 It is noted that the estimate soil chemistry values are below the human health screening values for a residential site end use with homegrown produce.

Ground Gas Generation

- 4.2.5 In accordance with current guidance (BS8576: 2013 and Wilson, Card and Haines (2009)) the ground gas generation potential of the underlying natural strata would be considered as being very low with a very low risk for on-site development and a negligible risk of lateral migration. Therefore, the natural ground anticipated on site is considered unlikely to be a significant source of ground gas generation.
- 4.2.6 Notwithstanding this, made ground if present, may provide a potential source of ground gas, subject to thickness subject to thickness and chemical composition.
- 4.2.7 The site is recorded to be within an Intermediate Probability radon area as between 1% and 3% of homes are estimated to be at or above the Action Level. It is reported that no radon protection measures are necessary in the construction of new dwellings or extensions.

Hydrogeology

- 4.2.8 The Envirocheck® report and Environment Agency information records the following hydrogeological setting of the site:

Table 4.2: Hydrogeological Setting

Geological Unit	Environment Agency Aquifer Designation	Environment Agency Aquifer Classification
River Terrace Deposits (Undifferentiated)	Secondary A Aquifer	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.
Lambeth Group	Secondary B Aquifer	Predominantly lower permeability layers which may store and yield limited amounts of groundwater due to localised features such as fissures, thin permeable horizons and weathering. These are generally the water-bearing parts of the former non-aquifers.
London Clay Formation	Unproductive Strata	These are rock layers or drift deposits with low permeability that have negligible significance for water supply or river base flow.

- 4.2.9 The underlying soils are reported as being of Intermediate (I1) to High (H1) Leaching Potential i.e. soils which can possibly or readily transmit liquid discharges because they are either shallow, or susceptible to rapid by-pass flow directly to rock, gravel or groundwater.
- 4.2.10 There is one registered groundwater abstraction licence located within 1000m of the site. This licence is recorded ~280m south-east of the site and relates to the extraction of groundwater for general agriculture use.

4.2.11 The site is not reported to lie within an Environment Agency groundwater Source Protection Zone.

4.2.12 There are two licensed discharge consents to land within 250m of the site, as follows:

Table 4.3: Licensed Discharge Consents

Receiving Water	Effluent Type	Distance	Direction
Into Land	Fleurie Nursery Ltd: Mixed Farming, Trade Discharge – Process Water	~95m	East
	Hedgehog Plants Trade Discharge – Process Water	~110m	South-west

4.2.13 It is reported within the Envirocheck® report that the site does not lie within an area susceptible for groundwater flooding to occur. In addition, the Environment Agency report the site to be located within an area of very low risk for flooding to occur.

4.2.14 Based upon the above information the geological and hydrogeological setting of the site is considered to be of **Low to Moderate Sensitivity**.

4.3 Hydrology

4.3.1 The closest surface water course to the site is a drain located on site, orientated north-south within the central southern area of the site. In addition, a network of streams and ditches are located within the surrounding area, from approximately 290m south-east and 350m west.

4.3.2 There are no recorded surface water abstraction points on or within 1000m of the site.

4.3.3 There are no discharge consents or pollution incidents to surface waters within 250m of the site as reported by Envirocheck®.

4.3.4 The site is not located within an area at risk from extreme flooding from rivers or the sea within. In addition, the Environment Agency indicates the site to be located within a Flood Zone 1 - land and property in flood zone 1 have a low probability of flooding.

4.3.5 Given the above information, the hydrology of the site is considered to be of **Low to Moderate Sensitivity**.

4.4 Environmental Data

4.4.1 Additional environmental data from the Envirocheck® report for the site is summarised in Table 4.4.

Table 4.4: Additional Environmental Data Summary

Category	0-250m	250-500m	Details
<i>Authorisations, Incidents and Registers</i>			
Substantiated Pollution Incident Register	0	1	~410m north-west – 22/01/2003 – Oils and Fuel – Mixed/Waste Oils: Water Impact – Category 3 – Minor Impact; Air Impact – Category 3 – Minor Impact; and

Category	0-250m	250-500m	Details
			Land Impact – Category 2 – Significant Impact.
<i>Waste Management</i>			
Historical Landfill	1	0	~245m south – Disused Canal at Barnham – Deposited Waste included Inert Waste.
Potentially Infilled Land (Non-Water) – Unknown Filled Ground (Pit, Quarry etc)	1	0	~160m east – 1992.
Potentially Infilled Land (Water) - Unknown Filled Ground (Pond, marsh, river, stream, dock etc);	0	8	~310m north – 1899; ~330m north – 1899; ~350m north – 1899; ~360m north-west – 1899; ~380m north-west – 1880; ~390m north – 1899; ~450m north – 1880; and ~450m north-east 1962.
<i>Current Land Uses</i>			
Potentially contaminative land uses	2	17	<u>0-250m</u> ~40m north-east – car body repairs; and ~180m north-west – horticultural equipment maintenance and repair. <u>250-500m including</u> ~290m north-west – road haulage services; ~330m north – footwear manufactures and suppliers; ~370m east – domestic appliances servicing, repairs and parts; ~420m north-west – blast cleaning; ~495m north-west – hardware manufacturers.
<i>Ecological Designated Areas</i>			
Nitrate Vulnerable Zone	1	0	<u>Onsite</u> Aldingbourne Rife (Surface Water)

4.5 Engineering Considerations

4.5.1 Engineering considerations identified from the Envirocheck® report for the site are summarised below:

Table 4.5: Engineering Considerations

Hazard	Hazard Potential					
	No Hazard	Negligible	Very Low	Low	Moderate	High
Collapsible ground				X		
Compressible ground	X					
Ground dissolution			X			
Landslide			X			
Running sand				X		
Shrink/swell clays					X	
Coal mining	X					
Non-coal mining	X					

4.5.2 Envirocheck® report is a single opencast mineral site within 1000m of the site, which has now ceased operation. Barnham Brick Field (~270m east) extracted common clay and shale of the River Terrace Deposited (Undifferentiated).

4.6 Regulatory Consultations

4.6.1 Environmental Health at Arun District Council have been contacted with regards to any potential contaminated land issues on site and within the surrounding area. The response has not been received in time for inclusion within this report. However, once received the information will be reviewed and the assessment updated if required.

4.7 Previous Site Report Summary

4.7.1 A number of historic reports and assessments produced for the site have been obtained from the Arun District Council planning portal for review. This information is within the public domain and has therefore been used in good faith as part of this assessment.

4.7.2 Whilst full reference should be made to the reports noted, a summary of the salient information they contain, in relation to the site, is provided in the following sections. It should be noted that TEC accept no responsibility for the accuracy of this third-party information.

Albury S.I. Ltd, Desk Study: 'Angels Nursery', Yapton Road, Barnham

4.7.3 This report is understood to have been produced for West Sussex County Council by Albury S.I Ltd (Report No. 09/8848/90, dated November 2009) and contained a review of available historic documentation and a walkover reconnaissance survey of the site.

Geo-Environmental Services Ltd, Desk Study and Ground Investigation Report – Angels Nursery, Yapton Road, Barnham

4.7.4 This report is understood to have been produced for Lovell Partnership Limited by Geo-Environmental Services Limited (Geo-Environmental) (Report No.: GE10423-GIR-SEP15, Version: Final, dated September 2015) and contained a review of available environmental and historical information, walkover reconnaissance survey of the site and ground investigation.

4.7.5 A review of salient information from the previously available desk study phases of the reports noted above are summarised below in Table 4.6.

Table 4.6: Desk Study Information Summary (Albury, 2009 and Geo-Environmental Services Ltd, 2015)

Site Reconnaissance	At the time of reporting, the site comprised two separate nurseries, Angels Nursery and Hyde Nursery, with Angels Nursery inactive and Hyde Nursery having limited operational use. The northern part of Angel's Nursery included 3No. large polytunnels, which appeared to have been in a state of disuse for a number of years. The site included a total of 4No. large glass or greenhouses, two at each nursery with some overgrown polytunnel frames noted in the south-western corner of the site. Waste was noted across the site, including brick rubble, waste plants and plastic bin bags. A residential property and a number of smaller ancillary buildings were present on the centre boundary between the two nurseries, these included a refrigerated storage container, toilet block and modern storage building. During the reconnaissance undertaken by Albury S.I. Ltd in 2009, 9No. separate above ground storage tanks were observed, one of which was noted to have leaked in the past with visual and olfactory observations indicating hydrocarbon contamination in the vicinity of the tank. It should be noted that no above ground storage tanks were reported by Geo-Environmental as part of their subsequent site reconnaissance in 2015. By 2015, the site was reported by Geo-Environmental to be vacant and was generally overgrown with grass and brambles. A series of ditches were noted to run parallel to each other from north-south within the south through portion of the site with a number of mature trees throughout the site. The central and north-western portions of the site comprised an area of open space with heavily disturbed ground with contained fragments of brick, concrete and reinforcing bars. It was noted that a number of concrete building footprints were present along the access road to the site.
Site History	The earliest available historic OS mapping, 1877, recorded the site to be undeveloped open land before being separated into 4No. separate plots by 1938 mapping, with a number of buildings present in the north of the site. The 1975 mapping indicated the site was occupied by a number of glasshouses (6No. to the east) and a number of smaller buildings present on the site. By 1989, a large greenhouse and associated tank, as well as a drain were indicated on OS mapping. The addition of two greenhouses were noted in the central portion of the site, replacing the smaller structures by 1994 OS mapping, with two further structures shown on 2006-2014 OS mapping located in the southern area of the site.
Surrounding Land Use	The immediate surrounding area was identified to be predominantly residential and agricultural purposes. The site is bounded by nurseries to the south and east, Yapton Road to the north and residential properties to the west. The South Coast Railway line is orientated east to west ~220m north of the site. Potentially significant features identified within the immediate vicinity of the site included nurseries (adjacent), a brickfield (~180m east) and a historic landfill (Chichester and Arundel Canal ~240m south).

Geology and Hydrogeology	The site was reported to be underlain by Aeolian Deposits, formerly the Brickearth, which are reported to be underlain by superficial Raised Beach Deposits, described by the British Geological Survey (BGS) as sand and gravel of roughly bedded flint or chert. The underlying solid geology was reported as the London Clay Formation, described by BGS as firm to stiff grey fissured clay, with interbedded and/or sub-ordinate beds of sand with concretions of argillaceous limestone and possible gypsum (selenite). The Raised Beach Deposits are reported to be designated by the Environment Agency as a Secondary A Aquifer. The underlying London Clay Formation is reported to be designated as Unproductive Strata. The site was not reported to be underlain by an Environment Agency Source Protection Zone and the nearest groundwater abstraction is located ~280m south-east of the site and used for spray irrigation. There are two reported discharge consents to land within 250m of the site have been identified; ~95m east for process water from mixed farming, now revoked and ~110m south-east for process water from undefined property.
Hydrology	The nearest surface water feature was recorded as to be an on-site drain, which runs down the centre of the site in a general north-south direction. The site is not reported to be located within an area at risk from flooding from river or seas. There were no reported discharge consents within 250m of the site and no surface water abstraction licences within 1000m of the site.
Ground Gas	Potential sources of ground gas identified in the preliminary assessment included potential made ground on site (subject to thickness and composition) and surrounding possible areas of infilled ground including the recorded landfill of the Chichester and Arundel Canal located approximately 240m south of the site and deposited waste included inert waste. The site was reported to be located within an Intermediate Radon Affected Area where between 1% and 3% of homes experience radon above the action level. However, no radon protection measures were reported to be necessary in the construction of new dwelling or extensions.
Outline Conceptual Model	The main potential Significant Pollutant Linkages identified within the preliminary assessments included: • Human Health (site workers and end users) – potential exposure to contaminants potentially present within underlying made ground and shallow soils (hydrocarbons, herbicides and pesticides and potential asbestos) through the dermal contact, ingestion and inhalation; • Controlled Waters (Secondary A Aquifer and on site drainage ditches) – leaching of contaminants within the unsaturated zone resulting in subsequent potential vertical and horizontal migration along preferential pathways; and • Human Health (end users) – migration and inhalation of ground gasses and vapours associated with the potential presence of made ground on site and off-site infilled canal.
Geotechnical Risk Assessment	Geo-Environmental reported the following factors that might impact on the geotechnical conditions of the site: • Potential made ground; • Laterally and vertically variable strata; • Volume change potential of the cohesive River Terrace Deposits; • Viability of soakaways; • The presence of trees on site; • The presence of shallow groundwater and/ or perched groundwater. The site was reported by Geo-Environmental as not being in an area affected by coal mining or non-coal mining.

4.8 Ground Investigation Summary (WSP, 2014 and Geo-Environmental Services Ltd, 2015)

- 4.8.1 A groundwater assessment was undertaken for the site by WSP (Report referenced 00040420, dated 08/07/2014). In addition, intrusive investigation work was undertaken by Geo-Environmental Services Limited (Report referenced GE10423-GIR-SEP15, dated September 2015).
- 4.8.2 A review of salient information from these phases of intrusive works is summarised below in Table 4.7.

Table 4.7 Intrusive Investigation Works – Summary

Ground Conditions	<u>WSP, 2014</u> WSP reported ground conditions at the site comprised made ground over Langley Silt, over Raised Beach Deposits and London Clay. <u>Geo-Environmental Services Ltd, 2015</u> The shallow ground materials were reported to comprise either topsoil (to a maximum depth of 0.3mbgl), or made ground (to a maximum depth of 0.95mbgl). The topsoil materials were recorded as typically light brown to brown and black clayey silt, slightly silty sandy clay with frequent rootlets and rare flint gravel. Made ground was encountered as brown silty sandy clay, clayey silt with occasional carbonaceous material with flint gravel and fragments of brick, concrete, cast iron, nails, cloth and glass. The underlying River Terrace Deposits were recorded to comprise an upper cohesive deposit, observed to depths between 0.85m and 2.0mbgl, and described as soft to stiff orangish brown, light greyish, brown, reddish brown clay with varying sandy and silt components. Occasional gravel of fine to medium sub-angular to sub-rounded flint. This was underlain by granular River Terrace Deposits, observed to depths of 2.6 – 3.0mbgl and described as loose becoming medium dense brown silty fine to medium sand. The underlying London Clay Formation was not encountered during the Geo-Environmental intrusive investigation works.
Groundwater	The groundwater assessment by WSP was undertaken between the winter months of December to April (2014) and groundwater conditions were reported to be artesian (flowing above the ground surface) in the eastern site boundary or at depths between 0.26m to 0.79mbgl across the remaining site area. Geo-Environmental reported groundwater strikes at depths between 2.0 and 2.95mbgl and dry monitoring wells during works undertaken in the summer months, between June – August 2015.
Contamination - Soils	Geo-Environmental reported the collection and laboratory analysis of 18No. samples, obtained from across the site and tested for a range of contaminants. Statistical analysis undertaken by Geo-Environmental identified outliers of PAH concentrations within shallow soils from WS6 at 0.2mbgl. It was considered that further testing/or remedial action would be required in order to protect end users in soft landscaping areas of the site. <u>Asbestos</u> All samples submitted were screened for asbestos with 'no asbestos detected' in all samples. <u>Pesticides</u> No pesticides were detected within the shallow soils on site. <u>Waste Acceptance Criteria</u> Analysis was undertaken on two samples of the made ground and a single sample of topsoil. The results indicated the topsoil material as

	potentially inert, while made ground samples were classified as both inert (HP2) and 'Stable non-reactive Hazardous' (HP1) due to exceedances of Total TPH in this sample (700mg/kg).
Contamination – Controlled Waters	Groundwater was reported by Geo-Environmental during the intrusive works at depths between 2.0m and 2.9mbgl. However, all installed wells were recorded to be dry during subsequent monitoring visits. Geo-Environmental considered the risk to groundwater or controlled waters to be negligible as the results of the laboratory testing on soils did not identify any specific source of gross or readily mobile, soil based contamination. This was reportedly supported by organoleptic evidence during the intrusive investigation.
Ground Gas	Based upon the ground gas data and assessment obtained during the monitoring period undertaken between June and August 2015, the ground gas conditions were identified as classified as Characteristic Situation 1 by Geo-Environmental. As such it was considered that no ground gas protection measures were required within the proposed development.
Foundations	On the basis of ground conditions encountered, Geo-Environmental reported that conventional foundations may be suitable for proposed development, founding within the underlying granular River Terrace Deposit recorded at depths of between 0.85m and 2.0mbgl.
Floor Slabs	Due to the presence of made ground recorded as >600mm bgl and shrinkable soils recorded as shallow depths, suspended floor slabs were recommended.
Protection of Concrete	The results of the water soluble sulphate and pH testing undertaken by Geo-Environmental indicated the buried concrete should be designed in accordance with Class DS-1 with an ACEC class of AC-1.
Soakage Potential	WSP reported that the drainage conditions on site would be described as poor by Carter & Bentley and that during winter conditions, it was considered unlikely that there would be a minimum of 1m unsaturated zone between the base of the soakaway and groundwater. Soakage testing was undertaken as part of the intrusive works by Geo-Environmental. It was reported that conventional soakaways were unlikely to perform satisfactorily on site and alternative options may need to be considered for the scheme.

4.9 Remediation Method Statement, Geo-Environmental Services Ltd (2015)

- 4.9.1 Geo-Environmental Services Limited produced a 'Remediation Method Statement' for *Angels Nursery, Yapton Road, Barnham, PO22 0AY* dated December 2015 and referenced GE15163-RMS-DEC15 based on the findings of the intrusive investigation.
- 4.9.2 The report stated that the proposed development strategy included the increase in ground levels by 400mm and 550mm across the site and that this would form part of the required cover system. Geo-Environmental recommended an overall cover system thickness of 600mm in private gardens and communal landscaping although it was noted that the depth of soil cover may need to be increased where planting is proposed e.g. for tree pits.

5 OUTLINE CONCEPTUAL MODEL**5.1 Introduction**

- 5.1.1 The assessment of potential risk associated with any identified contamination is based upon the identification and evaluation of Significant Pollutant Linkages.
- 5.1.2 A Significant Pollutant Linkage exists on a site only if three conditions are satisfied. These conditions are:
- *The presence of substances (potential contaminants / pollutants) that may cause harm (a **Source**)*
 - *The presence of a target which may be harmed e.g. site residents, groundwater (a **Receptor**)*
 - *A linkage between the Source and the Receptor e.g. ingestion of soil, inhalation of vapour (a **Pathway**)*
- 5.1.3 In each case, the existence of a pollutant linkage requires that not only does both a Source and a Receptor have to exist but that a demonstrable Pathway also exists. Therefore, the presence of measurable concentrations of contaminants within the ground or groundwater environment does not automatically imply that a contamination problem exists on site.
- 5.1.4 The nature and importance of both pathways and receptors, which are relevant to a particular site, will vary according to the actual or intended use of the site, its characteristics and its surroundings.
- 5.1.5 This process of the identification of Pollutant Linkages has been applied below to assess the potential risks associated with the site.

5.2 Hazard Identification

- 5.2.1 Potentially contaminative current and historic processes have been identified on and within the vicinity of the site and are presented in Table 5.1.

Table 5.1: Identified Potential Hazards

Potential Hazard/Source	Location	Details
Made Ground	On Site	Previous investigations undertaken by WSP and Geo-Environmental recorded the presence of areas of made ground at the site. Elevated concentrations of PAHs were reported by Geo-Environmental within the made ground in the central site area.
Potentially contaminative current and historic processes	On site	The site has historically been used for horticultural use (garden nursery). A site walkover undertaken as part of a previous desk study assessment by Albury S.I. Ltd in 2009 reported the presence of 9No. ASTs at the site, including one with evidence of leakage although the location of this tank is not specified. Geo-Environmental reported elevated PAH concentrations within the central area of the site only, when compared to generic assessment

Potential Hazard/Source	Location	Details
		criteria for a residential end use. In addition, concentrations of TPH up to 700mg/kg were recorded within a WAC sample collected from the central site area. No asbestos containing material and no pesticides were recorded within the shallow ground materials during the assessment undertaken by Geo-Environmental in 2015.
Potentially contaminative current and historic processes	Off Site	The surrounding land use predominantly comprised further areas of garden nurseries with associated tanks. A historical landfill is reported approximately 245m south of the site (disused canal at Barnham), reported to have accepted inert waste.

5.3 Potential Receptors and Pathways

5.3.1 Potential receptors identified as part of this preliminary risk assessment are:

- Current/future site users;
- Construction workers; and
- Controlled waters (Secondary A Aquifer, on site drainage ditch and surrounding surface water network)

5.3.2 Potential contaminant pathways relating to the identified receptors and contaminants of concern include:

- Dermal contact – contact with soil, dust or water;
- Ingestion – ingestion of soil, dust or water;
- Inhalation – inhalation of soil, dust or vapours;
- Vertical migration – e.g. seepage of contaminants at the ground surface (i.e. leakage/spillage of hydrocarbons) through cracks in hardstanding and/or leaching of contaminants within the unsaturated zone resulting in vertical contaminant migration; and
- Horizontal migration – e.g. lateral migration of contaminants within the saturated zone and along preferential pathways such as drainage pipe bedding.

5.4 Hazard Assessment and Risk Estimation

5.4.1 Potential significant pollutant linkages identified as part of this preliminary risk assessment are summarised in the Outline Site Conceptual Model presented in Table 5.2. References to risk estimations are made in accordance with the methodology presented in CIRIA publication C552 (2001) titled '*Contaminated Land Risk Assessment: A Guide to Good Practice*' and summarised in Appendix D.

Table 5.2: Outline Conceptual Model (Hazard Assessment and Risk Estimation)

Potential Hazard/ Source	Potential Receptor	Potential Pathway to Receptors	Associated Hazard	Scale of Impact	Potential Consequence of Source-Receptor Linkage	Potential Likelihood for Significant Source-Receptor Linkage	Risk Classification
Made Ground – On Site	Construction workers and site end users	Exposure to potential contaminants through inhalation, ingestion and dermal contact.	Risk of harm to human health	Local	Medium	Likely: Previous intrusive works undertaken at the site proved the presence of made ground to a maximum thickness of 0.95mbgl with recorded elevated PAH concentrations in relation to residential end use in the central site area.	Moderate Risk
	Controlled waters	Infiltration of water through the saturated zone resulting in the leaching of contaminants and vertical and lateral migration of contaminants through potential preferential pathways.	Risk of harm to controlled waters (Secondary A Aquifer and surface waters)	Local to Regional	Medium	Unlikely to Low Likelihood: Based on the laboratory analysis of the made ground previously recorded by Geo-Environmental, and given the reported generally cohesive nature of the upper River Terrace Deposits, the potential risk is considered to be low.	Low Risk
	Site end users, construction workers and proposed structures	Migration, ingress and inhalation of ground gasses.	Risk of harm to human health and proposed structures	Local	Medium to Severe	Unlikely: Intrusive works undertaken at the site to date have recorded made ground to be of relatively shallow thickness (<1m) and low total organic carbon content (average 0.89%). Therefore, the made ground on site is considered unlikely to be a potentially significant source of ground gas generation	Low Risk
Potentially contaminative current and historic processes – On Site	Construction workers and site end users Controlled waters	Exposure to potential contaminants through inhalation, ingestion and dermal contact. Vertical and horizontal migration of potential contaminants through preferential pathways in made ground and natural strata.	Risk of harm to human health Risk of harm to controlled waters (Secondary Aquifers and surface waters)	Local to Regional	Medium	Low Likelihood to Likely: A previous desk study reported the presence of 9no. ASTs at the former garden nursery on site, including evidence of potential leakage around one of these tanks. No evidence of gross contamination was identified during the intrusive works undertaken by Geo-Environmental. However, concentrations of PAH and TPH were recorded in the shallow soils. The potential for localised, residual contaminants elsewhere at the site cannot be discounted.	Low to Moderate Risk

Yapton Road, Barnham

Preliminary Geoenvironmental
and Geotechnical Assessment

Potential Hazard/ Source	Potential Receptor	Potential Pathway to Receptors	Associated Hazard	Scale of Impact	Potential Consequence of Source-Receptor Linkage	Potential Likelihood for Significant Source-Receptor Linkage	Risk Classification
Potentially contaminative current and historic processes – Off Site	Site end users, construction workers, controlled waters and proposed structures	Potential on-site migration of ground gas and contaminants from off-site sources.	Risk of harm to human health and controlled waters (Secondary Aquifers and surface waters)	Local to Regional	Medium to Severe	Unlikely to Low Likelihood: A number of garden nurseries with tanks are recorded in proximity to the site. However, Geo-Environmental recorded no evidence of gross contamination during intrusive works. An inert landfill is reported approximately 245m south of the site. Six rounds of ground gas monitoring were previously undertaken by Geo-Environmental. The site was characterised as CS1/ Green and no specific remedial action was considered to be warranted.	Low to Moderate Risk

6 INTRUSIVE INVESTIGATION**6.1 Background**

6.1.1 The ground investigation undertaken was designed to provide specific information regarding site conditions in support of the proposed site development.

6.1.2 In particular, the investigation was designed to provide further information on:

- Ground conditions to aid with the design of the development; and
- The potential significant pollutant linkages identified as part of the Preliminary Risk Assessment.

6.1.3 All site works were undertaken in accordance with BS5930:2015, BS10175+A1 (2013) and, where appropriate, Eurocode 7. Works were supervised by a suitably experienced geoenvironmental consultant from TEC.

6.2 Methodology

6.2.1 Exploratory works were undertaken between 20th and 22nd March 2018 and comprised;

- Advancement of 6No. cable percussive boreholes (BH1 to BH6) to depths of 12.0mbgl; and
- Advancement of 15No. trial pits (TP1 to TP15) to a maximum depth of 2.8mbgl.

6.2.2 Detailed descriptions of encountered ground conditions are shown on exploratory hole logs presented in Appendix E.

6.3 Field Testing

6.3.1 Standard Penetration Tests (SPTs) were undertaken at regular intervals within the cable percussive boreholes, between depths of 1.0m and 12.0mbgl, to gain an indicative strength profile of the underlying materials. The results are presented within Appendix E.

6.3.2 Where appropriate, hand shear vane (HSV) testing was undertaken on the cohesive natural ground material recovered from both the cable percussive borehole and the trial pits to determine in situ shear strength of the encountered materials. The results are presented within Appendix E.

6.3.3 In situ testing using Dynamic Cone Penetrometer (DCP-TRL) was undertaken in 10No. locations across the site to provide indicative CBR values for preliminary pavement design. The results of this testing are presented within Appendix J.

6.3.4 3No. shallow monitoring wells were installed to depths of 4.0mbgl within the superficial deposits to allow for monitoring of ground gas and groundwater levels. The locations of these monitoring wells are presented on Figure 3 and the results of the monitoring completed to date are presented within Appendix I.

6.4 Chemical Testing

6.4.1 Laboratory testing was scheduled on the basis of field observations.

6.4.2 Representative soil samples were collected and chemically tested at i2 Analytical Ltd, a UKAS/MCERTS accredited laboratory, for a selection of the following parameters:

Soils

- *Heavy metals;*
- *Calcium, magnesium, potassium and sodium;*
- *Phenol (monohydric), Cyanide (total, free and complex), ammonium, calcium carbonate, water soluble sulphate and pH;*
- *Total Organic Carbon (TOC);*
- *Speciated Polycyclic Aromatic Hydrocarbons (PAHs);*
- *Total Petroleum Hydrocarbons (TPH CWG), including BTEX;*
- *Volatile Organic Compounds (VOCs);*
- *Semi-Volatile Organic Compounds (SVOCs);*
- *Asbestos fibre screen and quantification; and*
- *Basic Characterisation (including Waste Acceptance Criteria) testing.*

Waters

- *Heavy metals;*
- *Calcium, magnesium, potassium and sodium;*
- *Phenol (monohydric), Cyanide (total, free and complex), ammonium, calcium carbonate, water soluble sulphate and pH;*
- *Total Organic Carbon (TOC);*
- *Speciated Polycyclic Aromatic Hydrocarbons (PAHs);*
- *Total Petroleum Hydrocarbons (TPH CWG), including BTEX;*
- *Volatile Organic Compounds (VOCs); and*
- *Semi-Volatile Organic Compounds (SVOCs).*

6.4.3 Geochemical certificates of analysis are presented Appendix F and Basic Characterisation (WAC) certificates of analysis are presented in Appendix G.

6.5 Geotechnical Testing

6.5.1 Selected soil samples were submitted for geotechnical analysis at i2 Analytical Ltd and K4 Soils Laboratory. Laboratory testing was scheduled upon the basis of field observations for a selection for:

- Moisture Content;
- Plasticity Indices;
- Particle Size Distribution;
- Quick Undrained Triaxial Tests; and
- BRE SD1 - acid and water soluble sulphate, total sulphur and pH.

6.5.2 Soil geotechnical certificates of analysis are presented in Appendix H and the BRE SD1 chemical tests are presented in Appendix F.

6.6 General Sampling

6.6.1 Soil samples were collected directly into pre-labelled sample containers. During the course of the sampling care was taken to minimise head space of the sample

containers. Once filled sample containers were placed within cool boxes containing ice packs to maintain as cool a temperature as possible, nominally 4°C.

- 6.6.2 Samples were collected by courier for delivery to the selected laboratories. All samples were accompanied by detailed chain of custody sheets.

7 ENCOUNTERED GROUND CONDITIONS**7.1 Introduction**

7.1.1 A summary of encountered ground conditions for the site is provided below.

7.1.2 Detailed descriptions of encountered ground conditions are shown on exploratory hole logs presented in Appendix E.

Made Ground

7.1.3 Made ground was encountered at locations across the site to depths between 0.25m and 0.6mbgl and was typically recorded to comprise grey clayey gravelly sand or sandy very gravelly clay, with gravel of flint, concrete, glass, plastic, concrete, ceramic clinker and mudstone recorded. In addition, localised fragments of textile, string and wood were noted.

7.1.4 Geo-Environmental previously recorded made ground to a maximum depth of 0.95mbgl at the site.

7.1.5 No made ground materials were recorded within the exploratory hole locations typically positioned around the peripheries of the site. Near surface soils within these locations were recorded to comprise topsoil type material of dark brown sandy clay with occasional fine gravel of flint and frequent rootlets to observed depths of 0.1m to 0.3mbgl. Geo-Environmental previously recorded topsoil materials to depths of 0.25 – 0.3mbgl.

Natural Ground

7.1.6 The natural ground materials were recorded to comprise a succession of cohesive River Terrace Deposits, underlain by granular River Terrace Deposits. The encountered superficial deposits were noted to be consistent with those previously reported by Geo-Environmental.

7.1.7 The superficial deposits were underlain by the London Clay Formation, encountered at depths between 4.0 and 6.3mbgl. Red mottled grey sandy clay, considered to be associated with the Reading Formation of the Lambeth Group, was encountered in BH6 only in the south-west corner of the site, underlying the London Clay Formation deposits.

7.2 Generalised Ground Profile

7.2.1 The general ground profile encountered at the site, from both the TEC and Geo-Environmental (depths in *italics*) phase of works, is summarised in Table 7.1 below.

Table 7.1: Generalised Ground Profile

Top (mbgl)	Base (mbgl)	Ground Conditions
0.0 <i>0.0</i>	0.25/0.30 <i>0.25/0.30</i>	<i>Topsoil Type Material:</i> Brown slightly sandy slightly gravelly sandy clay.
0.0 <i>0.0</i>	0.25/0.8 <i>0.25/0.95</i>	<i>Made Ground:</i> Grey-brown and brown gravelly sandy clay. Gravel of flint, brick and occasional concrete.
0.25/0.8 <i>0.25/0.95</i>	1.3/2.5 <i>0.85/2.0</i>	<i>River Terrace Deposits (Cohesive):</i> Soft to firm low to medium strength slightly gravelly sandy clay.

Top (mbgl)	Base (mbgl)	Ground Conditions
1.3/2.5 0.85/2.0	4.0/6.3 2.6/3.0	River Terrace Deposits (Granular): Typically medium dense, locally dense, orangish-brown slightly clayey, becoming gravelly, sand.
4.0/6.3	>12	London Clay Formation: Stiff high to very high strength grey silty clay.
6.0	>12	BH6 only (SW corner) Lambeth Group (Reading Formation): Stiff very high strength red mottled grey sandy silty clay.

7.3 Groundwater and Perched Water

7.3.1 Water strikes encountered during TEC's site works are shown on the exploratory hole logs in Appendix E and summarised in Table 7.2 below.

Table 7.2: Groundwater Strikes

Location	Date	Groundwater Strike (mbgl)	Strata
BH2	21/03/2018	3.5	River Terrace Deposits
BH3	21/03/2018	3.0	
BH4	21/03/2018	2.0	
BH5	21/03/2018	2.0	
BH6	22/03/2018	3.0	
TP2	21/03/2018	1.15	
TP3	21/03/2018	1.5	
TP4	21/03/2018	2.1	
TP5	21/03/2018	1.6	
TP10	22/03/2018	1.6	
TP13	22/03/2018	1.7	
TP14	22/03/2018	1.8	

7.3.2 Groundwater strikes were recorded during the intrusive works at depths between 1.1m and 3.0mbgl, although were noted to rise within the boreholes to depths between 0.8m and 1.0m.

7.3.3 Geo-Environmental previously reported groundwater strikes at depths between 2.0 and 2.95mbgl and dry monitoring wells during works undertaken in the summer months – June – August 2015.

7.3.4 As part of the groundwater assessment undertaken by WSP between the winter months of December to April (2014), groundwater conditions were reported to be artesian (flowing above the ground surface) in the eastern site boundary, or at depths between 0.26m to 0.79mbgl elsewhere.

7.3.5 The investigation works to date therefore indicate the presence of a shallow groundwater body within the superficial deposits, which appears to be responsive to seasonal variations in precipitation.

7.3.6 Following completion of the site works, groundwater levels were gauged within the installed monitoring wells as part of the ground gas monitoring. The results of the

monitoring are presented in Appendix I and groundwater levels are summarised below in Table 7.3.

Table 7.3: Groundwater Levels

Location	Date	Groundwater Levels (mbgl)	Strata
BH2	09/04/2018	0.74	River Terrace Deposits
BH5	09/04/2018	0.67	
BH6	09/04/2018	0.9	
BH2	16/04/2018	0.95	
BH5	16/04/2018	1.03	
BH6	16/04/2018	1.08	
BH5	11/06/2018	Dry	
BH6	11/06/2018	1.95	

7.4 Contamination Summary

7.4.1 No visual or olfactory evidence of significant contamination was observed on site during the intrusive works.

8 CONTAMINATION CHARACTERISATION**8.1 Legislation**

8.1.1 Contaminated Land is defined in Part IIA of the Environmental Protection Act (1990) as:

8.1.2 "Any land which appears to the Local Authority in whose area it is situated to be in such a condition, by reasons of substances in, on or under the land that:

- Significant harm is being caused or there is a significant possibility of such harm being caused;

or

- *significant pollution of controlled waters is being caused or there is a significant possibility of such pollution being caused."

**Section 86 of the Water Act 2003 amends section 78A of Environmental Protection Act 1990 for Controlled Waters.*

8.2 Generic Quantitative Risk AssessmentHuman Health Screening

8.2.1 Current legislation and guidance on the assessment of contaminated land promotes a tiered risk approach (CLR 11). The generic quantitative risk assessment comprises a screening of identified contaminants against generic guideline values that are appropriate to the site setting and the receptors concerned. For risks to human health the basis for these generic guideline values are the methodologies set out by the Environment Agency's Contaminated Land Exposure Assessment (CLEA) guidelines.

8.2.2 The following regulatory and industry guidance has been utilised for the selection of Generic Assessment Criteria utilised as part of the GQRA. The order of the guidance listed is in terms of hierarchy for selection of GACs (where the land uses and parameters are considered most applicable).

1. *Category 4 Screen Levels (C4SLs) – DEFRA (2014)*
2. *Soil Guidance Values (SGVs) – Environment Agency (2009)*
3. *Suitable for Use Levels (S4ULs) – LQM/CIEH (2015)*
4. *EIC/AGS/CL:AIRE GAC (2009)*

8.2.3 The C4SLs for arsenic, cadmium, chromium (VI) and lead have been utilised as part of the GQRA. Benzene and benzo(a)pyrene C4SLs have not been utilised as part of the Tier 1 screening as they are based upon 6% soil organic matter (SOM) as opposed to 1% SOM utilised by LQM/CIEH (2015).

8.2.4 SGVs have been utilised, where appropriate, for dioxins, furans and dioxin-like PCBs; nickel; inorganic mercury and selenium (residential SGV used for proposed residential end use). SGVs for organic compounds are not utilised as they are derived using a 6% soil organic matter as opposed to 1% SOM utilised by LQM/CIEH (2015).

8.2.5 In the absence of a published UK derived GAC for cyanide, the GQRA for total cyanide is based upon comparison of recorded values against the Dutch Intervention Value for free cyanide (VROM 2000).

8.2.6 S4ULs and EIC/AGS/CL:AIRE GACs are adopted for the remaining potential contaminants using the hierarchy noted above.

8.2.7 The purpose of the site investigation was to provide information to establish the suitability of the site for a residential development. Therefore, the standard land use for the site, for use in the generic assessment, has been defined as "*Residential with homegrown produce*" in accordance with current guidance.

Controlled Waters Screening

8.2.8 Risks to controlled waters have been assessed following current Environment Agency guidance such as "*Remedial Targets Methodology – Hydrogeological Risk Assessment for Land Contamination*". This guidance describes a tiered approach to the assessment and, if necessary, derivation of clean up targets for soils and groundwater with the emphasis on the protection of controlled waters.

8.2.9 In accordance with Environment Agency guidance, a Level 2 groundwater generic screening assessment has been undertaken, based on the findings of the sampling undertaken as part of this phase of works, to identify the contaminants of concern that may pose a risk to controlled waters. This assessment has been undertaken by the comparison of groundwater contaminant concentrations with criteria applicable to the long term protection of water quality.

8.2.10 Based on our conceptual understanding, the nearest significant controlled water receptor is considered to be the on site ditches and the Secondary A Aquifer of the superficial River Terrace Deposits, which is considered likely to provide baseflow to surface waters. Therefore, analytical results have been assessed against Freshwater Environmental Quality Standards (EQS) where available. Where such standards are not available, analytical results have been conservatively assessed against the World Health Organisation (WHO) Guidelines for Drinking Water Quality (2011), WHO Petroleum Products in Drinking-water (2008) or the Water Supply (Water Quality) Regulations 2016.

Ground Gas Screening

8.2.11 An initial qualitative risk screening assessment based upon the methodology for characterising gassing sites detailed within the following documents has been undertaken:

- CIRIA Report C665 (2007) '*Assessing risks posed by hazardous ground gases to buildings (revised)*';
- CL:AIRE RB17 (2012) '*A pragmatic approach to ground gas risk assessment*';
- NHBC (March 2007) '*Guidance on evaluation of development proposals on sites where methane and carbon dioxide are present*';
- BS8485:2015 '*Code of Practice for the characterisation and remediation from ground gas in affected developments*';
- BS8576:2013 '*Guidance on investigations for ground gas – Permanent gases and Volatile Organic Compounds (VOCs)*'; and
- Wilson S., Card C. and Haines S. (2009) '*Ground Gas Handbook*'.

8.2.12 The objectives of the screening assessment are to provide a general characterisation of the ground materials within the site based on the investigation works undertaken to-date. This information is used to provide a preliminary assessment of gassing potential for the materials encountered at the site. This, together with ground gas

data collected as part of the monitoring undertaken to date, is used to provide a qualitative conceptual model of identified risk in relation to the proposed development.

8.3 Soil Analysis - Human Health

8.3.1 Soil samples were collected and analysed from both made ground and encountered near surface materials. Certificates of analysis for samples are contained within Appendix F.

8.3.2 Current regulatory guidance for the statistical assessment of environmental data within a contaminated land context is detailed within the CIEH and CL:AIRE joint publication titled '*Guidance on Comparing Soil Concentration Data with a Critical Concentration*' (2008). However, as judgemental sampling has been undertaken, statistical assessment as detailed in CL:AIRE (2008) has not been carried out as part of this assessment. Therefore, to identify Contaminants of Potential Concern (COPC) as part of this preliminary assessment, the analytical results for the ground materials sampled have been assessed by the screening of individual analyses against the relevant Tier 1 Site Screening Values (SSVs) adopted.

8.3.3 For generic assessment purposes, SSVs have been conservatively selected, where appropriate, based upon a sandy soil and Soil Organic Matter (SOM) of 1%.

Made Ground / Near Surface Materials

8.3.4 18No. samples of made ground and near surface materials were scheduled for analysis from the site. The results obtained from made ground are summarised in Table 8.1 below:

Table 8.1: Soil Analysis Summary

Contaminant	Max (mg/kg)	Min (mg/kg)	SSV (mg/kg)	No. of Tests	No. of Exceedances
Arsenic	33	10	37 ⁽¹⁾	18	0
Boron	4.6	0.58	290 ⁽³⁾	18	0
Cadmium	5.0	0.18	22 ⁽¹⁾	18	0
Chromium	61	20	910 ⁽³⁾	18	0
Chromium (VI)	<0.5 ⁽⁶⁾	<0.5 ⁽⁶⁾	21 ⁽¹⁾	18	0
Copper	14000	15	2400 ⁽³⁾	18	2
Lead	700	28	200 ⁽¹⁾	18	2
Mercury	0.27	<0.1 ⁽⁶⁾	170 ⁽²⁾	18	0
Nickel	65	14	130 ⁽²⁾	18	0
Selenium	<0.2 ⁽⁶⁾	<0.2 ⁽⁶⁾	350 ⁽²⁾	18	0
Zinc	1700	91	3700 ⁽³⁾	18	0
Beryllium	2.7	<1.0 ⁽⁶⁾	1.7 ⁽³⁾	18	1
Vanadium	65	20	410 ⁽³⁾	18	0
Barium	630	59	1300 ⁽⁴⁾	18	0
Cyanide (Total)	<0.5 ⁽⁶⁾	<0.5 ⁽⁶⁾	20 ⁽⁵⁾	18	0
Total Phenol (Monohydric)	<0.3 ⁽⁶⁾	<0.3 ⁽⁶⁾	120 ⁽³⁾	18	0
Water Soluble Sulphate (SO ₄) – g/l	0.4	<0.01 ⁽⁶⁾	-	18	0
Sulphide	22	0.54	-	18	0
pH	9.6	6.5	-	18	0
Naphthalene	0.59	<0.1 ⁽⁶⁾	2.3 ⁽³⁾	18	0
Acenaphthylene	1.9	<0.1 ⁽⁶⁾	170 ⁽³⁾	18	0
Acenaphthene	3.4	<0.1 ⁽⁶⁾	210 ⁽³⁾	18	0

Contaminant	Max (mg/kg)	Min (mg/kg)	SSV (mg/kg)	No. of Tests	No. of Exceedances
Fluorene	2.8	<0.1 ⁽⁶⁾	170 ⁽³⁾	18	0
Phenanthrene	30	<0.1 ⁽⁶⁾	95 ⁽³⁾	18	0
Anthracene	7.2	<0.1 ⁽⁶⁾	2400 ⁽³⁾	18	0
Fluoranthene	62	0.1	280 ⁽³⁾	18	0
Pyrene	51	0.13	620 ⁽³⁾	18	0
Benzo(a)anthracene	30	<0.1 ⁽⁶⁾	7.2 ⁽³⁾	18	2
Chrysene	38	<0.1 ⁽⁶⁾	15 ⁽³⁾	18	2
Benzo(b)fluoranthene	56	<0.1 ⁽⁶⁾	2.6 ⁽³⁾	18	2
Benzo(k)fluoranthene	19	<0.1 ⁽⁶⁾	77 ⁽³⁾	18	0
Benzo(a)pyrene	37	<0.1 ⁽⁶⁾	2.2 ⁽³⁾	18	2
Indeno(1,2,3-cd)pyrene	36	<0.1 ⁽⁶⁾	27 ⁽³⁾	18	2
Dibenz(a,h)anthracene	8.3	<0.1 ⁽⁶⁾	0.24 ⁽³⁾	18	3
Benzo(g,h,i)perylene	33	<0.1 ⁽⁶⁾	320 ⁽³⁾	18	0
Total PAH	420	<2.0 ⁽⁶⁾	-	18	0
Benzene	<1.0 ⁽⁷⁾	<1.0 ⁽⁷⁾	0.087 ⁽³⁾	18	0
Toluene	<1.0 ⁽⁶⁾	<1.0 ⁽⁶⁾	130 ⁽³⁾	18	0
Ethylbenzene	<1.0 ⁽⁶⁾	<1.0 ⁽⁶⁾	47 ⁽³⁾	18	0
p & m-xylene	<1.0 ⁽⁶⁾	<1.0 ⁽⁶⁾	56 ⁽³⁾	18	0
o-xylene	<1.0 ⁽⁶⁾	<1.0 ⁽⁶⁾	60 ⁽³⁾	18	0
MTBE	<1.0 ⁽⁶⁾	<1.0 ⁽⁶⁾	49 ⁽³⁾	18	0
TPH Aliphatic C5-C6	<1.0 ⁽⁶⁾	<1.0 ⁽⁶⁾	42 ⁽³⁾	18	0
TPH Aliphatic C6-C8	<1.0 ⁽⁶⁾	<1.0 ⁽⁶⁾	100 ⁽³⁾	18	0
TPH Aliphatic C8-C10	<1.0 ⁽⁶⁾	<1.0 ⁽⁶⁾	27 ⁽³⁾	18	0
TPH Aliphatic C10-C12	<1.0 ⁽⁶⁾	<1.0 ⁽⁶⁾	130 ⁽³⁾	18	0
TPH Aliphatic C12-C16	<1.0 ⁽⁶⁾	<1.0 ⁽⁶⁾	1100 ⁽³⁾	18	0
TPH Aliphatic C16-C21	<1.0 ⁽⁶⁾	<1.0 ⁽⁶⁾	65000 ⁽³⁾	18	0
TPH Aliphatic C21-C35	34	<1.0 ⁽⁶⁾		18	0
TPH Aromatic C5-C7	<1.0 ⁽⁶⁾	<1.0 ⁽⁶⁾	70 ⁽³⁾	18	0
TPH Aromatic C7-C8	<1.0 ⁽⁶⁾	<1.0 ⁽⁶⁾	130 ⁽³⁾	18	0
TPH Aromatic C8-C10	<1.0 ⁽⁶⁾	<1.0 ⁽⁶⁾	34 ⁽³⁾	18	0
TPH Aromatic C10-C12	3.1	<1.0 ⁽⁶⁾	74 ⁽³⁾	18	0
TPH Aromatic C12-C16	20	<1.0 ⁽⁶⁾	140 ⁽³⁾	18	0
TPH Aromatic C16-C21	240	<1.0 ⁽⁶⁾	260 ⁽³⁾	18	0
TPH Aromatic C21-C35	1700	<1.0 ⁽⁶⁾	1100 ⁽³⁾	18	1

Notes:

- 1 DEFRA C4SLs (2014) based on "Residential with homegrown produce" end use
- 2 Environment Agency SGVs (2009) based on "Residential" end use
- 3 LQM/CIEH S4ULs (2015) based on "Residential with homegrown produce" end use
- 4 CL:AIRE, AGS & EIS (2009) based on "Residential" end use
- 5 Dutch Intervention Value for free cyanide (VROM 2000)
- 6 Reported as Laboratory Limit of Detection (LOD)
- 7 Laboratory Limit of Detection (LOD) is greater than SSV screening value

8.3.5 Exceedances of the Tier 1 SSVs for copper, lead, beryllium and a number of PAH compounds were recorded within samples of the made ground from BH6, TP6, TP14 and TP15.

8.3.6 In addition, concentrations of petroleum hydrocarbons (TPH Aromatic C21-C35 fraction) were recorded to exceed the Tier 1 SSV within the shallow made ground sampled from TP6 (0.1m).

8.3.7 It should be noted that total concentrations of TPH (mineral oil) of 1500mg/kg (TP12 at 0.1mbgl), 990mg/kg (TP14 at 0.1mbgl) and 1600mg/kg (TP15 at 0.3mbgl),

together with total PAH of 360mg/kg (TP15 at 0.3mbgl), have been recorded as part of the WAC testing.

8.3.8 Concentrations of volatile organic compounds (VOCs) were recorded below the laboratory limit of detection (LOD) in all samples.

8.3.9 An asbestos screen was undertaken on all samples of the made ground, no asbestos was detected.

8.4 Controlled Waters - Groundwater Analysis

8.4.1 Groundwater samples were taken from 3No. locations. Certificates of analysis are contained in Appendix F with results being summarised below in Table 8.2.

Table 8.2: Groundwater Analysis Summary

Contaminant	Max (µg/l)	Min (µg/l)	SSV (µg/l)	No. of Tests	No. of Exceedances
pH	8.3	7.8	-	3	0
Total Cyanide	<50	<50	50 ⁽⁵⁾	3	0
Sulphate as SO4	220000	54000	400000 ⁽¹⁾	3	0
Ammonium as NH4	61	<50	500 ⁽⁵⁾	3	0
Total Phenols (monohydric)	<30	<30	-	3	0
Naphthalene	<0.10	<0.10	2 ⁽¹⁾	3	0
Acenaphthylene	<0.10	<0.10	0.10 ⁽⁵⁾	3	0
Acenaphthene	<0.10	<0.10	-	3	0
Fluorene	<0.10	<0.10	-	3	0
Phenanthrene	<0.10	<0.10	-	3	0
Anthracene	<0.10	<0.10	0.1 ⁽¹⁾	3	0
Fluoranthene	<0.10	<0.10	0.0063 ⁽¹⁾	3	0
Pyrene	<0.10	<0.10	-	3	0
Benzo(a)anthracene	<0.10	<0.10	-	3	0
Chrysene	<0.10	<0.10	-	3	0
Benzo(b)fluoranthene	<0.10	<0.10	0.017 ⁽²⁾	3	0
Benzo(k)fluoranthene	<0.10	<0.10	0.017 ⁽²⁾	3	0
Benzo(a)pyrene	<0.10	<0.10	0.27 ⁽²⁾	3	0
Indeno(1,2,3-cd)pyrene	<0.10	<0.10	0.00017 ⁽¹⁾	3	0
Dibenz(a,h)anthracene	<0.10	<0.10	-	3	0
Benzo(ghi)perylene	<0.10	<0.10	0.0082 ⁽²⁾	3	0
Antimony	<1.0	<1.0	10 ⁽⁵⁾	3	0
Arsenic	3.4	1.3	50 ⁽¹⁾	3	0
Barium	54	31	700 ⁽⁶⁾	3	0
Beryllium	<1.0	<1.0	-	3	0
Boron	130	39	2000 ⁽¹⁾	3	0
Cadmium	1.0	<0.080	1.5 ^(1,3)	3	0
Chromium (III)	9.0	3.2	32 ⁽²⁾	3	0
Cobalt (dissolved)	27	<1.0	-	3	0
Copper (dissolved)	19	2.2	2000 ⁽⁵⁾	3	0
Lead (dissolved)	4.8	<1.0	14 ⁽²⁾	3	0
Manganese (dissolved)	700	38	123 ⁽⁴⁾	3	2
Mercury (dissolved)	<0.50	<0.50	0.07 ⁽²⁾	3	0
Molybdenum (dissolved)	13	<1.0	70 ⁽⁶⁾	3	0

Contaminant	Max (µg/l)	Min (µg/l)	SSV (µg/l)	No. of Tests	No. of Exceedances
Nickel (dissolved)	26	2.8	34 ⁽²⁾	3	0
Selenium (dissolved)	110	9.1	10 ⁽⁵⁾	3	1
Tin (dissolved)	<1.0	<1.0	-	3	0
Vanadium (dissolved)	1.9	<1.0	-	3	0
Zinc (dissolved)	90	4.8	10.9 ⁽⁴⁾	3	1
Calcium	120000	61000	-	3	0
Magnesium	10000	5700	-	3	0
Potassium	22000	4000	-	3	0
Sodium	380000	44000	200000 ⁽⁵⁾	3	1
Chloride	76000	66000	250000 ⁽⁵⁾	3	0
Iron	490	260	200 ⁽⁵⁾	3	3
Phosphorus	110	<20	-	3	0
Benzene	<1	<1	0.0028 ⁽²⁾	3	0
Toluene	<1	<1	50 ⁽²⁾	3	0
Ethylbenzene	<1	<1	74 ⁽¹⁾ /380 ⁽²⁾	3	0
p & m-xylene	<1	<1	300 ⁽⁶⁾	3	0
o-xylene	<1	<1		3	0
MTBE (Methyl Tertiary Butyl Ether)	<1	<1	-	3	0
Mineral Oil (C10 - C40)	<10	<10	-	3	0
TPH-CWG - Aliphatic >C5 - C6	<0.10	<0.10	15000 ⁽⁷⁾	3	0
TPH-CWG - Aliphatic >C6 - C8	<0.10	<0.10	15000 ⁽⁷⁾	3	0
TPH-CWG - Aliphatic >C8 - C10	<0.10	<0.10	300 ⁽⁷⁾	3	0
TPH-CWG - Aliphatic >C10 - C12	<0.10	<0.10	300 ⁽⁷⁾	3	0
TPH-CWG - Aliphatic >C12 - C16	<0.10	<0.10	300 ⁽⁷⁾	3	0
TPH-CWG - Aliphatic >C16 - C21	<0.10	<0.10	-	3	0
TPH-CWG - Aliphatic >C21 - C35	<0.10	<0.10	-	3	0
TPH-CWG - Aromatic >C5 - C7	<0.10	<0.10	10 ⁽⁷⁾	3	0
TPH-CWG - Aromatic >C7 - C8	<0.10	<0.10	700 ⁽⁷⁾	3	0
TPH-CWG - Aromatic >C8 - C10	<0.10	<0.10	300 ⁽⁷⁾	3	0
TPH-CWG - Aromatic >C10 - C12	<0.10	<0.10	90 ⁽⁷⁾	3	0
TPH-CWG - Aromatic >C12 - C16	<0.10	<0.10	90 ⁽⁷⁾	3	0
TPH-CWG - Aromatic >C16 - C21	<0.10	<0.10	90 ⁽⁷⁾	3	0
TPH-CWG - Aromatic >C21 - C35	<0.10	<0.10	90 ⁽⁷⁾	3	0

Notes:

- 1 EQS, Annual Average (AA) – Freshwaters
- 2 EQS, Maximum Allowable Concentration (MAC) - Freshwaters
- 3 EQS – Maximum Allowable Concentration (MAC) - Freshwaters calcium carbonate >200mg/l – based on reported hardness of 307mg/l for site area (Portsmouth Waters)
- 4 Bioavailable dissolved concentration – EQS, Freshwaters
- 5 Water Supply (Water Quality Regulations) 2016
- 6 WHO Guidelines for Drinking Water Quality (2016)
- 7 WHO Petroleum Products in Drinking Water (2008)

8.4.2 Concentrations of all organic constituents (PAHs, TPH, VOCs and SVOCs) were all recorded to be below the laboratory limit of detection within the sampled groundwater.

8.4.3 Exceedances were recorded for manganese, selenium, zinc and sodium. However, based on the total soil concentrations recorded and presence of generally cohesive near surface ground materials, these concentrations are considered likely to represent natural background concentrations in the area. In addition, the use of drinking water standards is considered overly conservative as there are no reported drinking water

abstractions within 1000m of the site, the site is not located within a Source Protection Zone and the superficial deposits are underlain by the Unproductive Strata of the London Clay Formation.

8.5 Waste

- 8.5.1 Basic Characterisation testing and WAC testing, was undertaken on 16no. samples of the shallow made ground and natural soils at locations across the site, in accordance with the guidance outlined within the Environment Agency document 'Waste Sampling and Testing for Disposal to Landfill' (EBPRI 11507B; March 2013)'.
- 8.5.2 Based upon Table 5.3 of the guidance, the WAC tests results (Appendix G) indicate that the shallow natural soils may be classified as inert waste, although some elevated total organic carbon concentrations (3.8% - 6.7%) have been recorded within these samples when compared to WAC values, corresponding concentrations of dissolved organic carbon (DOC) were recorded <500mg/kg.
- 8.5.3 The general made ground materials may also be classified as inert waste, with the exception of shallow made ground in the central site area (TP6, TP12, TP14, TP15), where concentrations of PAHs and TPH (mineral oil) are recorded to exceed the criteria for inert waste.
- 8.5.4 However, it should be noted that while this initial assessment gives classifications based on industry guidance, the final decision with regard to waste acceptance classification is dependent upon the individual landfill operator. Therefore it is recommended that the Basic Characterisation test results, WAC tests data, as well as all total contaminant results and background information regarding the waste source and origin (as contained within this report) are forwarded to the selected landfill/waste facility to gain confirmation with regards to the acceptability of the waste materials that may be generated from the site.
- 8.5.5 It should also be noted that inert, non-hazardous and hazardous waste must be treated before it can be sent to landfill, in accordance with the requirements of the Landfill Directive and in the context of these works treatment could include "source segregation". This would involve careful separation of waste material types on site to demonstrate the minimisation of the disposal of waste to landfill.

8.6 Ground Gas

- 8.6.1 2No. rounds of ground gas monitoring have been undertaken by TEC to date.
- 8.6.2 All gas monitoring was undertaken using a calibrated GFM 430 infra red gas analyser fitted with an internal flow pod. The monitoring results are presented in Appendix I and summarised in Table 8.3 below.

Table 8.3: Summary of Ground Gas Monitoring Data

Borehole	Response Zone/Strata	Evidence of potential source of ground gas	No. of monitoring occasions	Maximum Methane (%)	Maximum Carbon dioxide (%)	Minimum Oxygen (%)	Maximum Flow (l/hr)	Water levels (mbgl)	Range of atmospheric pressure (mb)
BH2	(Superficial -River Terrace Deposits)	None observed. Inert landfill - infilled canal reported ~245m south of the site)	2	0.0	2.2	11.9	1.6	0.74 – 0.95	1006 – 1015
BH5			2	0.0	8.6	13.9	1.3	0.67 – 1.03	1004 – 1015
BH6			2	0.0	0.6	5.4	1.5	0.90 – 1.08	1005 – 1015

- 8.6.3 Atmospheric pressures were recorded between 1004mb and 1015mb during the 2No. monitoring rounds and were noted to be relatively low and falling during the initial monitoring undertaken on the 9th April 2018.
- 8.6.4 Maximum flow rates between 1.3l/hr and 1.6l/hr were recorded during the monitoring. No measurable levels of methane were recorded within any of the boreholes (i.e. 0%v/v). Concentrations of carbon dioxide were recorded between 0.1% and 8.6%v/v. Only a single monitoring event recorded carbon dioxide above 5%v/v and this was on 06 June 2018 when a level of 8.6%v/v was recorded from BH5. BH5 was observed to be dry at this time with a negative flow rate initially being recorded. Given the remaining site records and the initial negative flow rate recorded this elevated level is not considered representative of site conditions.
- 8.6.5 No elevated concentrations of hydrogen sulphide, carbon monoxide or Lower Explosive Limit (% LEL) were recorded during the monitoring visits.
- 8.6.6 Shallow groundwater levels were recorded within each of the monitoring wells, although within the screened section during the duration of the monitoring (i.e. the monitoring wells were not completely flooded).

On Site Ground Gas Sources

- 8.6.7 No significant thickness of made ground or evidence of organic deposits was recorded on site during the intrusive investigations. Average total organic carbon (TOC) concentrations of the made ground and near surface soils were recorded to be low (<3%) based on laboratory analysis from both the TEC and Geo-Environmental phases of work. In addition, no elevated VOCs were recorded with the sampled ground material.

Off Site Ground Gas Sources:

- 8.6.8 A historical landfill (infilled canal) is reported approximately 245m south of the site. However, this is downgradient of the site and is reported to have last accepted inert waste in the 1970s. Therefore, the potential for significant on-site ground gas migration from this feature is considered to be low.

Gas Screening Values

- 8.6.9 On the basis of the gas monitoring undertaken to-date by TEC, the site would be characterised in accordance with current guidance as having a worst case GSV of 0.0l/hr for methane (based upon a maximum flow rate of 1.6l/hr and maximum recorded concentration of 0.0%v/v) and 0.042l/hr for carbon dioxide (based upon a maximum flow rate of 1.6l/hr and maximum concentration of 2.6%v/v).
- 8.6.10 The results are noted to be consistent with those previously reported by Geo-Environmental Services Ltd following 6no. rounds of ground gas monitoring at the site.

Characteristic Situation

- 8.6.11 On the basis of the site conceptual model, and the monitoring undertaken at the site to date by both Geo-Environmental and TEC, the site may be placed into Characteristic Situation 1 (CS1) and no ground gas protection measures would be considered to be required within the proposed development.
- 8.6.12 No radon protective measures are reported to be required for the site.

9 REFINED CONCEPTUAL MODEL**9.1 Introduction**

- 9.1.1 The Preliminary Risk Assessment undertaken as part of this report identified the presence of potential significant pollutant linkages associated with the site and surrounds. Therefore, in accordance with the approach recommended in CLR11, additional information was collected about the site and its surroundings as part of a Generic Quantitative Risk Assessment. Based upon this additional information and the proposed development layout, the site conceptual model has been refined and pollutant linkages confirmed for evaluation where considered necessary.

9.2 Hazard Identification

- 9.2.1 Potential sources of contamination have been identified on and within the vicinity of the site and are presented in Table 9.1.

Table 9.1: Identified Hazards

Identified Hazard/Source	Location	Details
Made ground	On site	Made ground has been recorded across the site to depths up to 0.95mbgl (reported by Geo-Environmental). Elevated concentrations of heavy metals, PAHs and localised TPH have been recorded within the sampled made ground, in relation to Tier 1 SSVs for a residential site end use.
Potentially contaminative current and historic processes	On and off site	The site is understood to have housed 9no. above ground storage tanks during its use as a garden nursery. Surrounding land uses were identified to comprise further areas of garden nurseries with associated tanks. No evidence of significant contamination has been recorded at the site during intrusive works undertaken by TEC and Geo-Environmental. In addition, no organic contaminants of potential concern (CoPC) were recorded within the sampled groundwater.
Infilled canal – ground gas	Off site	A historic inert area of landfill (infilled canal) is recorded 245m south (downgradient) of the site. GSVs derived from both the TEC and Geo-Environmental monitoring indicate the site may be placed into CS1.

9.3 Identified Potential Receptors and Pathways

- 9.3.1 Potential receptors identified as part of the generic risk assessment are:

- Current/future site users;
- Construction workers; and
- Controlled waters (Secondary A Aquifer and surface waters)

- 9.3.2 Potential contaminant pathways identified as part of the generic risk assessment include:
- Dermal contact – contact with soil, dust or water;
 - Ingestion - ingestion of soil, dust or water;
 - Inhalation – inhalation of soil, dust or vapours;
 - Vertical migration – e.g. leaching of contaminants recorded within made ground resulting in vertical contaminant migration; and
 - Horizontal migration – e.g. lateral migration of contaminants/ ground gases within the unsaturated zone and along preferential pathways.

9.4 Hazard Assessment and Risk Estimation

- 9.4.1 Potential significant pollutant linkages identified following completion of the intrusive works are summarised in the Refined Site Conceptual Model presented in Table 9.2.

Table 9.2: Refined Conceptual Model (Hazard Assessment and Risk Estimation)

Identified Hazard/ Source	Identified Receptor	Potential Pathway to Receptors	Associated Hazard	Scale of Impact	Potential Consequence of Source-Receptor Linkage	Potential Likelihood for Significant Source-Receptor Linkage	Risk Classification
Made Ground – On Site	Construction workers and site end users	Exposure to potential contaminants through inhalation, ingestion and dermal contact.	Risk of harm to human health	Local	Medium	Likely: Elevated PAH, heavy metal and localised TPH concentrations have been recorded within the made ground in relation to a residential end use.	Moderate Risk
	Controlled waters	Infiltration of water through the saturated zone resulting in the leaching of contaminants and vertical and lateral migration of contaminants through potential preferential pathways.	Risk of harm to controlled waters (Secondary A Aquifer and surface waters)	Local to Regional	Medium	Unlikely: Based on the generally limited thickness of the encountered made ground, no field evidence of gross contamination, the laboratory analytical results of the made ground and groundwater on site, and given the reported generally cohesive nature of the upper River Terrace Deposits, the potential risk to controlled water from the made ground on site is considered to be low.	Low Risk
	Site end users, construction workers and proposed structures	Migration, ingress and inhalation of ground gasses.	Risk of harm to human health and proposed structures	Local	Medium to Severe	Unlikely: Intrusive works undertaken at the site to date have recorded made ground to be of relatively shallow thickness (<1m) and low total organic carbon content (average <3%). Therefore, the made ground on site is considered unlikely to be a potentially significant source of ground gas generation	Low Risk
Potentially contaminative current and historic processes – On and Off Site	Construction workers and site end users Controlled waters	Exposure to potential contaminants through inhalation, ingestion and dermal contact. Vertical and horizontal migration of potential contaminants through preferential pathways in made ground and natural strata.	Risk of harm to human health Risk of harm to controlled waters (Secondary Aquifers and surface waters)	Local	Medium	Low Likelihood: No evidence of significant contamination has been recorded at the site during intrusive works undertaken by TEC and Geo-Environmental. In addition, no organic contaminants of potential concern (CoPC) were recorded within the sampled groundwater.	Low to Moderate Risk
Inert Landfill (Ground Gas) – Off Site	Site end users, construction workers and proposed structures	Potential on-site migration of ground gas from off-site landfill	Risk of harm to human health and proposed structures	Local	Medium	Unlikely: The infilled canal is located ~245m downgradient of the site. Eight rounds of ground gas monitoring undertaken by Geo-Environmental and TEC at the site to date indicate it may be classified as CS1.	Low Risk

10 GROUND ENGINEERING**10.1 Proposed Development**

10.1.1 It is understood that it is proposed to develop the site comprising the construction of approximately 95 homes with associated hard infrastructure and soft landscaping.

10.1.2 While full details of the proposed scheme have not been made available to TEC at this stage, information provided to date indicate the properties will comprise 2 – 2.5 storeys. Therefore, for the purpose of this preliminary assessment, line loads of up to 100kN per metre run have been assumed for the proposed residential development.

Site Preparation

10.1.3 Underground utilities are understood to be present at the site. Consideration should be given to removal or re-alignment of any underground, as appropriate.

10.1.4 Several mature trees were observed both within and around the perimeter of the site and evidence of recently cut trees was also noted. In addition, areas of concrete hardstanding were observed within areas of the site. Appropriate consideration to these features will be required.

10.2 Ground Conditions

10.2.1 The general ground profile encountered at the site during both phases of intrusive works by TEC and Geo-Environmental (depths recorded in italics) is summarised in Table 10.1 below.

Table 10.1: Generalised Ground Profile

Top (mbgl)	Base (mbgl)	Ground Conditions
0.0	0.25/0.30	Topsoil Type Material: Brown slightly sandy slightly gravelly sandy clay.
0.0 <i>0.0</i>	0.25/0.8 <i>0.25/0.95</i>	Made Ground: Grey-brown and brown gravelly sandy clay. Gravel of flint, brick and occasional concrete.
0.25/0.8 <i>0.25/0.95</i>	1.3/2.5 <i>0.85/2.0</i>	River Terrace Deposits (Cohesive): Soft to firm low to medium strength slightly gravelly sandy clay.
1.3/2.5 <i>0.85/2.0</i>	4.0/6.3 <i>2.6/3.0</i>	River Terrace Deposits (Granular): Typically medium dense, locally dense, orangish-brown slightly clayey, becoming gravelly, sand.
4.0/6.3	>12	London Clay Formation: Stiff high to very high strength grey silty clay.
6.0	>12	BH6 only (SW corner) Lambeth Group (Reading Formation): Stiff very high strength red mottled grey sandy silty clay.

Made Ground

10.2.2 No geotechnical testing was undertaken on samples of the made ground. However, as a part of the geochemical testing undertaken for the site, pH and sulphate testing was undertaken on samples of encountered made ground. The test data indicated

sulphate concentrations in the range of <10mg/l and 400mg/l and pH values of 6.5 to 9.6

Natural Strata

- 10.2.3 Geotechnical test results for the natural strata are discussed below. Geotechnical laboratory test certificates are provided in Appendix H with in situ tests being presented on the exploratory hole logs in Appendix E of this report.

Superficial Deposits –River Terrace Deposits

- 10.2.4 Geotechnical laboratory analysis was undertaken on 4no. samples of the superficial River Terrace Deposits, as summarised in Table 10.2 below.

Table 10.2: Summary of Laboratory Test Results –River Terrace Deposits

Test	Number of Tests	Range of Results
Plasticity Index (%)	2	17 – 19
Moisture Content (%)	2	19 – 23
% passing 425µm sieve	2	90 - 95
Particle Size Distribution	2	See below
pH Value	3	7.5 – 7.7
Total Sulphur	3	0.01 – 0.02
Water Soluble SO ₄ (g/l in soil)	3	<0.01 – 0.03
Total SO ₄ (Acid Soluble %))	3	<0.01 – 0.05

Upper Cohesive Superficial Deposits

- 10.2.5 The Plasticity Indices of the upper cohesive River Terrace Deposits ranged between 17% and 19%, corresponding to Modified Plasticity Indices between approximately 16.2% and 17.1%. However, it should be noted that Geo-Environmental previously recorded Modified Plasticity Indices of these materials between 9% and 25%. The results indicate these deposits to be of low to medium volume change potential, as defined by NHBC (2018).
- 10.2.6 Hand shear vane (HSV) testing undertaken on the encountered upper cohesive superficial deposits recorded shear strengths of between 30kPa and 80kPa, with an average of 40kPa. These results are noted to be in broad agreement with the SPT data, with 'N' values between 7 and 14 recorded in these deposits.
- 10.2.7 Geo-Environmental reported variable results from pocket penetrometer tests undertaken on these materials, with results between 0.5kg/cm² and 4.5kg/cm² recorded, inactive of undrained strengths of greater than 25kN/m². In addition, Geo-Environmental reported correlated SPT 'N' values between 0 and 12 based on the results of dynamic probe super heavy (DPSH) testing, indicative of undrained strengths of up to 75kN/m².
- 10.2.8 A characteristic strength of 40kN/m² is considered appropriate for these materials based on all relevant field data.
- 10.2.9 Using standard correlations with the SPT data, e.g. Stroud (1988), estimated consolidation parameters obtained for these upper cohesive materials would suggest

a coefficient of compressibility, m_v , of approximately between $0.125\text{m}^2/\text{MN}$ and $0.3\text{m}^2/\text{MN}$ with a tentative characteristic value of $0.2\text{m}^2/\text{MN}$, indicative of generally medium compressible materials.

Lower Granular Superficial Deposits

- 10.2.10 Particle Size Distribution (PSD) tests were undertaken on 2No. samples of the deeper granular River Terrace Deposits, recorded from depths of 1.3m to a maximum depth of 6.3mbgl. The results indicate these materials typically comprise a slightly silty, clayey, gravelly sand, with fines ($<63\mu\text{m}$) content recorded between 15% and 21%, indicating these deposits are not shrinkable in accordance with NHBC. It should be noted that previous testing undertaken by Geo-Environmental were in broad agreement, recording fine contents of between 7% and 18%.
- 10.2.11 The SPT data recorded during TEC's intrusive works indicates these natural granular ground materials to be generally consistent in density across the site. SPT 'N' values were recorded between 11 and 17 within the granular deposits at depths between 2m and 3mbgl indicate these materials to be medium dense. Where a localised greater thickness of superficial deposits was encountered (BH4 and BH5), SPT 'N' values between 31 and 34 were recorded at a depth of 4.0m, indicating dense granular deposits.
- 10.2.12 The dynamic probe super heavy tests undertaken by Geo-Environmental reportedly indicated correlated SPT 'N' values between 3 and 26, although generally with values >10 recorded, for these granular materials. However, it is noted that the London Clay Formation was not proven as part of the window sampling works undertaken by Geo-Environmental and therefore any correlations with the results obtained from depths of below $\sim 3\text{m}$ are considered tentative.
- 10.2.13 Based on the SPT data for these deposits, a characteristic friction value (ϕ') of approximately 40° may be appropriate for these materials (Schmertmann, 1975).

London Clay Formation/ Lambeth Group

- 10.2.14 Geotechnical laboratory analysis was undertaken on 5no. samples of the London Clay Formation; and a single sample of the Lambeth Group (Reading Formation) encountered in the south-west corner of the site only. The results are summarised in Table 10.3 below.

Table 10.3: Summary of Laboratory Test Results –London Clay Formation/ Lambeth Group

Test	Number of Tests	Range of Results
<i>London Clay Formation</i>		
Plasticity Index (%)	3	49 - 53
Moisture Content (%)	3	28 - 37
% passing $425\mu\text{m}$ sieve	3	98 - 100
pH Value	4	8.2 - 8.6
Total Sulphur (%)	4	0.26 - 0.58
Water Soluble SO_4 (g/l in soil)	4	0.13 - 0.61
Total SO_4 (Acid Soluble %)	4	0.051 - 0.21
Unconsolidated Undrained Triaxial (Cu - kPa)	4	44 - 119

Test	Number of Tests	Range of Results
<i>London Clay Formation</i>		
<i>Lambeth Group (Reading Formation)</i>		
Plasticity Index (%)	1	31
Moisture Content (%)	1	17
% passing 425µm sieve	1	100
pH Value	1	8.8
Total Sulphur (%)	1	0.016
Water Soluble SO ₄ (g/l in soil)	1	<0.010
Total SO ₄ (Acid Soluble %)	1	<0.010
Unconsolidated Undrained Triaxial (Cu - kPa)	1	50 – 73

- 10.2.15 The Plasticity Indices of the London Clay Formation materials ranged between 49% and 53%, corresponding to Modified Plasticity Indices between approximately 48% and 52%, suggesting these materials to be of high volume change potential (NHBC 2018). The Plastic Index and Modified Plastic Index of the encountered Lambeth Group (BH6 only) was recorded as 31%, suggesting these materials to be of medium volume change potential.
- 10.2.16 Quick undrained triaxial testing undertaken on 4no. undisturbed samples of both the London Clay Formation and Lambeth Group materials, at depths between 5m and 9.5m, recorded undrained strengths between 44kPa and 119kPa. Typically, the test results indicate these materials to be of medium to high strength.
- 10.2.17 Hand shear vane testing undertaken on the encountered London Clay Formation and Lambeth Group indicated a general increase in undrained shear strength with depth, with results ranging from 60kPa to 150kPa at depths <6mbgl, indicative of medium to high strength materials, and 150kPa to >250kPa below depths of 6m, indicative of very high strength materials.
- 10.2.18 SPT 'N' values were also recorded to generally increase with depth in the London Clay Formation and Lambeth Group materials, with average 'N' values of approximately 19 at 5m depth, increasing to average 'N' values of 34 at 12m depth.
- 10.2.19 Based on the available information, a characteristic undrained strength of $c_u = 15z - 20\text{kN/m}^2$, where z is the depth in metres below ground level, is considered to be appropriate for design purposes for the London Clay Formation and Lambeth Group encountered below depths of 4.0m.

Foundations

- 10.2.20 The ground conditions on site have been recorded to comprise made ground (locally topsoil type material), underlain by superficial River Terrace Deposits, underlain in turn by the London Clay Formation. The Lambeth Group (Reading Formation) was encountered in a single borehole (BH6) located in the south-west corner of the site.
- 10.2.21 Shallow groundwater has been recorded within the superficial deposits on site, with resting levels recorded at depths between 0.67m and 1.08mbgl during monitoring visits for this phase of works. Previous assessments at the site indicate this shallow groundwater body may be seasonally variable, with groundwater recorded to be locally

at the surface during winter months (WSP, 2014) and at depths >2.0mbgl during summer months (Geo-Environmental, 2015).

Preliminary Foundation Design Recommendations

- 10.2.22 On the basis of the ground and groundwater conditions recorded at the site, conventional foundations may be suitable founding on the medium dense granular River Terrace Deposits encountered at depths of 1.3 – 2.5m across the site where construction can be undertaken within the drier months and assuming that the water levels fall sufficiently during such periods. Consequently, additional groundwater monitoring would be recommended in order to determine likely seasonal variations.
- 10.2.23 When founding on these deposits, and assuming the water can be controlled to remain below the depth of the excavations, a preliminary allowable bearing resistance in the region of 100kN/m² may be considered appropriate when considering strip foundations of up to 1m in width.
- 10.2.24 However, should groundwater levels be high during construction, conventional footings may not be feasible due to potential significant water ingress into excavations and a piled foundation solution may be appropriate.
- 10.2.25 The proximity of nearby structures and the environmental sensitivity of the site will need to be carefully considered when choosing the most appropriate pile type and it is suggested that a specialist piling contractor should be consulted regarding the piling options and detailed design of most appropriate option. Notwithstanding this, it is anticipated that CFA, or potentially driven piles, would be most suitable within the encountered ground.
- 10.2.26 Consequently, based on the available information and for *budget purposes only*, when utilising a single CFA pile, an estimated resistance of approximately 220kN may be derived for a 300mm diameter pile in excess of 10m (i.e. founding within the London Clay Formation/ Lambeth Group). It should be noted that where pile groups are utilised, depending on the pile spacing, there may be the need to deepen and/or widen the piles to achieve the same resistance per pile. However, it would be recommended that advice from a specialist piling contractor is obtained regarding the most economical solution for the site.
- 10.2.27 Given the reported medium volume change potential of the cohesive near surface materials, suitable voids may be required below and against ground beams and where appropriate against the sides of foundations. The NHBC guidance (2018) recommends a minimum void space of 25mm against the sides of ground beams and foundations and 100mm below ground beams.

10.3 Ground Floor Slabs

- 10.3.1 Made ground greater than 600mm below current ground level has been recorded at the site. NHBC Standards require floor slabs to be suspended where the depth of made ground exceeds 600mm or where foundations extend below 1.0mbgl.
- 10.3.2 Where a suspended floor is utilised, it is recommended that an appropriate void be incorporated into the design in accordance with the recommendation made by the NHBC. Given the low to medium volume change potential of the encountered upper materials, NHBC guidance indicates a void of a minimum void of 100mm should be utilised where suspended in situ concrete flooring is incorporated into the design and where pre-cast concrete suspended floors are used a minimum void space of 250mm should be utilised to allow for 150mm of ventilation.

10.4 Preliminary Pavement Design

- 10.4.1 Dynamic Cone Penetrometer (DCP-TRL) testing was undertaken at 10no. locations across the site, as shown on Figure 3. The results are presented in full in Appendix J.
- 10.4.2 Using the calculations outlined in Jones CR and J Rolt (1991), the results indicate adjusted Californian Bearing Ratio (CBR) values between 2.4% and 11.9%, although characteristically between approximately 3% and 4%, below an assumed formation level of 500mmbgl.
- 10.4.3 Further, based on correlations with plasticity indices using the Design Manual for Roads and Bridges IAN 73/06 Revision 1 (2009) and observations made on site during the intrusive works, CBR values between 4% and 5% are indicated for the upper cohesive natural deposits.
- 10.4.4 Therefore, based on field observations and testing and the calculations outlined above, a preliminary CBR value of 3% may be appropriate where formation is proven to be within natural deposits. In addition, given the localised thickness of made ground encountered onsite (greater than 600mm), a CBR value of <2.5% would be recommended for preliminary design purposes where road formation is proven to be within potential made ground deposits owing to the inherent variability of this material
- 10.4.5 It should be noted that all road formations should be proof rolled and soft spots removed and replaced with selected granular fill and, where adoptable, a pavement of sufficient thickness to prevent the penetration of frost should be employed.

10.5 Excavations

- 10.5.1 Excavation of the materials immediately beneath the site should be achievable using conventional excavation plant.
- 10.5.2 Shallow groundwater levels have been recorded at the site, particularly during the winter months, and therefore appropriate consideration will need to be given to the potential for significant groundwater ingress, which may occur during excavations.

10.6 Protection of Buried Concrete

- 10.6.1 The results of the water soluble sulphate and pH testing carried out the made ground and shallow natural ground (River Terrace Deposits), indicate that in general accordance with BRE Special Digest 1 (2005), these materials yield an Aggressive Chemical Environment for Concrete (ACEC) of AC-1 requiring a Design Sulphate Class of DS-1. Geo-Environmental also previously provided this recommendation for shallow soils at the site.
- 10.6.2 Testing of the Lambeth Group encountered in the south-west corner of the site only also indicated an ACEC of AC-1 requiring a Design Sulphate Class of DS-1.
- 10.6.3 However, selenite crystals were recorded within the encountered London Clay deposits. Based on the total potential sulphate concentrations, as outlined in BRE SD1 for natural ground with pyrite recorded to be present, the London Clay deposits yield an Aggressive Chemical Environment Class (ACEC) of AC-4 requiring Design Sulphate Class DS-4.
- 10.6.4 Consequently, it is considered that a Design Sulphate Class of DS-4 is required where the London Clay deposits are subject to disturbance during construction.

10.7 Drainage

- 10.7.1 Soakage testing has not been undertaken at the site as part of these works. However, monitoring of groundwater levels has been undertaken, with shallow resting levels recorded at depths between 0.67m and 1.08mbgl during monitoring visits for this phase of works. Previous assessments at the site also indicated this shallow groundwater body may be seasonally variable, with groundwater recorded to be locally at the surface during winter months (WSP, 2014) and at depths >2.0mbgl during summer months (Geo-Environmental, 2015).
- 10.7.2 On the basis of the shallow groundwater levels recorded at the site, it is considered unlikely that the use of soakaways will be feasible.

11 CONCLUSIONS & RECOMMENDATIONS**11.1 Conclusions**

11.1.1 Tweedie Evans Consulting Ltd (TEC) has been appointed by Wates Construction Limited to undertake a preliminary geoenvironmental and geotechnical assessment of Barnham Road, Yapton. All works were undertaken in accordance with our proposal letter dated 07 March 2018 and referenced 1801024.001_003.bidlet.

11.1.2 The site is an area of land, formerly understood to have been occupied by a garden nursery (Angel's Nursery), located off Yapton Road, to the south-east of Barnham.

11.1.3 The proposed development is understood to comprise the construction of 95No. low rise residential units with associated parking and private gardens.

11.2 Geoenvironmental Assessment

11.2.1 The site is considered to be of low to moderate environmental sensitivity due primarily to the superficial River Terrace Deposits designated as a Secondary A Aquifer, which is considered likely to provide baseflow to nearby surface waters (including on site ditches).

11.2.2 Potentially contaminative land uses identified on site included reported former above ground storage tanks (ASTs) associated with the former Angel's Nursery on site. These were not present at the time of these assessment works. No visual or olfactory evidence of potentially significant contamination was observed during the intrusive works at the site by TEC, or during previous works undertaken by Geo-Environmental.

11.2.3 In addition, laboratory analysis of both soil and groundwater did not indicate the presence of potentially significant and widespread hydrocarbon impact associated with the former ASTs.

11.2.4 Made ground was recorded across the site to a maximum depth of 0.8m (0.95m reported by Geo-Environmental). Laboratory analysis of representative made ground materials recorded the exceedance of Tier 1 SSVs for a number of PAHs, heavy metals and localised heavy end hydrocarbons (TPH Aromatic C21-C35). The findings were noted to be consistent with those previously reported by Geo-Environmental.

11.2.5 An area of inert landfill, comprising an infilled canal reported to have taken waste in the 1970s is recorded approximately 245m south of the site. However, this feature is located downgradient of the site and given its limited size, distance from the site and on the basis of the monitoring undertaken to date, the potential risk of significant on-site ground gas migration is considered to be low.

11.2.6 Therefore, based upon our current conceptual understanding of the site and proposed end use, the following Significant Pollutant Linkages have been identified:

- Human health (future site end users and construction workers) - exposure to potential contaminants (PAHs, heavy metals and heavy end TPH) within made ground at the site via the ingestion, dermal contact and inhalation pathways.

11.3 Geoenvironmental Risk Management RecommendationsIdentification of Feasible Remediation Options

11.3.1 Significant risks identified within the conceptual model can be mitigated through the breaking of the significant pollution linkage by the removal of at least the source, receptor or pathway. Within reference to the site's conceptual models the following

preliminary remediation approach has been prepared. This preliminary remediation approach will need to be presented in more detail within a Remediation Strategy, the content of which will require agreement in writing of the Regulatory Authorities prior to commencing any remediation on site.

Human Health

11.3.2 Given the presence of elevated contaminant concentrations within the made ground encountered at the site, it is recommended that a suitable cover system be provided within the areas proposed for soft landscaping in this part of the site. Notwithstanding this, further analysis of the made ground (and potentially the natural ground) may be undertaken to confirm the presence, or otherwise, of elevated contaminant concentrations within proposed soft landscaped areas following site preparation/ site strip works. The presence of hardstanding would also mitigate against the potential risks to site end users from the identified general contamination within the made ground.

11.3.3 Given the presence of made ground across the site and identified contaminants, good brownfield site working practices should be adopted by construction workers to mitigate against identified potential risks.

11.3.4 Should water pipes be placed within the made ground on site, due consideration should be given to the UK Water Industry Research Ltd (UKWIR) guidance.

Controlled Waters

11.3.5 On the basis of the soil and groundwater laboratory analytical results and the conceptual site model, no significant risk has been identified to controlled waters receptors at this stage and no remedial action would be considered to be required.

Ground Gas

11.3.6 The monitoring to date and the conceptual site model indicate the site may be classified as CS1 and no ground gas protection measures would be considered to be required within the proposed development.

Waste

11.3.7 Based the testing undertaken to date and current guidance, the shallow natural soils may be classified as inert waste, although some elevated total organic carbon concentrations (3.8% - 6.7%) have been recorded within these samples when compared to WAC values, corresponding concentrations of dissolved organic carbon (DOC) were recorded <500mg/kg.

11.3.8 The general made ground materials may also be classified as inert waste, with the exception of shallow made ground in the central site area (TP6, TP12, TP14, TP15), where concentrations of PAHs and TPH (mineral oil) are recorded to exceed the criteria for inert waste.

11.3.9 It should be noted that while this initial assessment gives classifications based on industry guidance, the final decision with regard to waste acceptance classification is dependent upon the individual landfill operator.

11.4 Ground Engineering

11.4.1 On the basis of the ground and groundwater conditions recorded at the site, conventional foundations may be suitable founding on the medium dense granular

River Terrace Deposits encountered at depths of 1.3 – 2.5m across the site where construction can be undertaken within the drier months and assuming that the water levels fall sufficiently during such periods.

- 11.4.2 Consequently, additional groundwater monitoring would be recommended in order to determine likely seasonal variations.
- 11.4.3 When founding on these deposits, and assuming the water can be controlled to remain below the depth of the excavations, a preliminary allowable bearing resistance in the region of 100kN/m² may be considered appropriate when considering strip foundations of up to 1m in width.
- 11.4.4 However, should groundwater levels be high during construction, conventional footings may not be feasible due to water ingress into excavations and a piled foundation solution may be appropriate.
- 11.4.5 The proximity of nearby structures and the environmental sensitivity of the site will need to be carefully considered when choosing the most appropriate pile type and it is suggested that a specialist piling contractor should be consulted regarding the piling options and detailed design of most appropriate option. Notwithstanding this, it is anticipated that CFA piles would be most suitable within the encountered ground.
- 11.4.6 Based on the available information, for budgetary and indicative purposes only, a pile resistance in the order of 220kN is anticipated for a single 300mm CFA pile to a depth of approximately 10mbgl (i.e. founding within the London Clay Formation/ Lambeth Group). However, it would be recommended that advice from a specialist piling contractor is obtained regarding the most economical solution for the site.
- 11.4.7 Given the reported medium volume change potential of the underlying ground materials, suitable voids may be required below and against ground beams and where appropriate against the sides of foundations.

11.5 Ground Floor Slabs

- 11.5.1 Made ground greater than 600mm below current ground level has been recorded at the site. NHBC Standards require floor slabs to be suspended where the depth of made ground exceeds 600mm or where foundations extend below 1.0mbgl.
- 11.5.2 Where a suspended floor is utilised, due to the shallow cohesive deposits of low to medium volume change potential, it is recommended that an appropriate void be incorporated into the design in accordance with the recommendations made by the NHBC.

11.6 Preliminary Pavement Design

- 11.6.1 Based on field observations and testing undertaken to date, a preliminary CBR value of 3% may be appropriate where formation is proven to be within natural deposits. In addition, given the localised thickness of made ground encountered onsite (greater than 600mm), a CBR value of <2.5% would be recommended for preliminary design purposes where road formation is proven to be within potential made ground deposits owing to the inherent variability of this material
- 11.6.2 It should be noted that all road formations should be proof rolled and soft spots removed and replaced with selected granular fill and, where adoptable, a pavement of sufficient thickness to prevent the penetration of frost should be employed.

11.7 Excavations

- 11.7.1 Excavation of the materials immediately beneath the site should be achievable using conventional excavation plant.
- 11.7.2 Shallow groundwater levels have been recorded at the site, particularly during the winter months, and therefore appropriate consideration will need to be given to the potential for significant groundwater ingress, which may occur during excavations.

11.8 Protection of Buried Concrete

- 11.8.1 The results of the water soluble sulphate and pH testing carried out the made ground and shallow natural ground (River Terrace Deposits) and the Lambeth Group, indicate that in general accordance with BRE Special Digest 1 (2005), these materials yield an Aggressive Chemical Environment for Concrete (ACEC) of AC-1 requiring a Design Sulphate Class of DS-1.
- 11.8.2 However, selenite crystals were recorded within the encountered London Clay deposits. Based on the total potential sulphate concentrations, as outlined in BRE SD1 for natural ground with pyrite recorded to be present, the London Clay deposits yield an Aggressive Chemical Environment Class (ACEC) of AC-4 requiring Design Sulphate Class DS-4.
- 11.8.3 Consequently, it is considered that a Design Sulphate Class of DS-4 is required where the London Clay deposits are subject to disturbance during construction.

11.9 Drainage

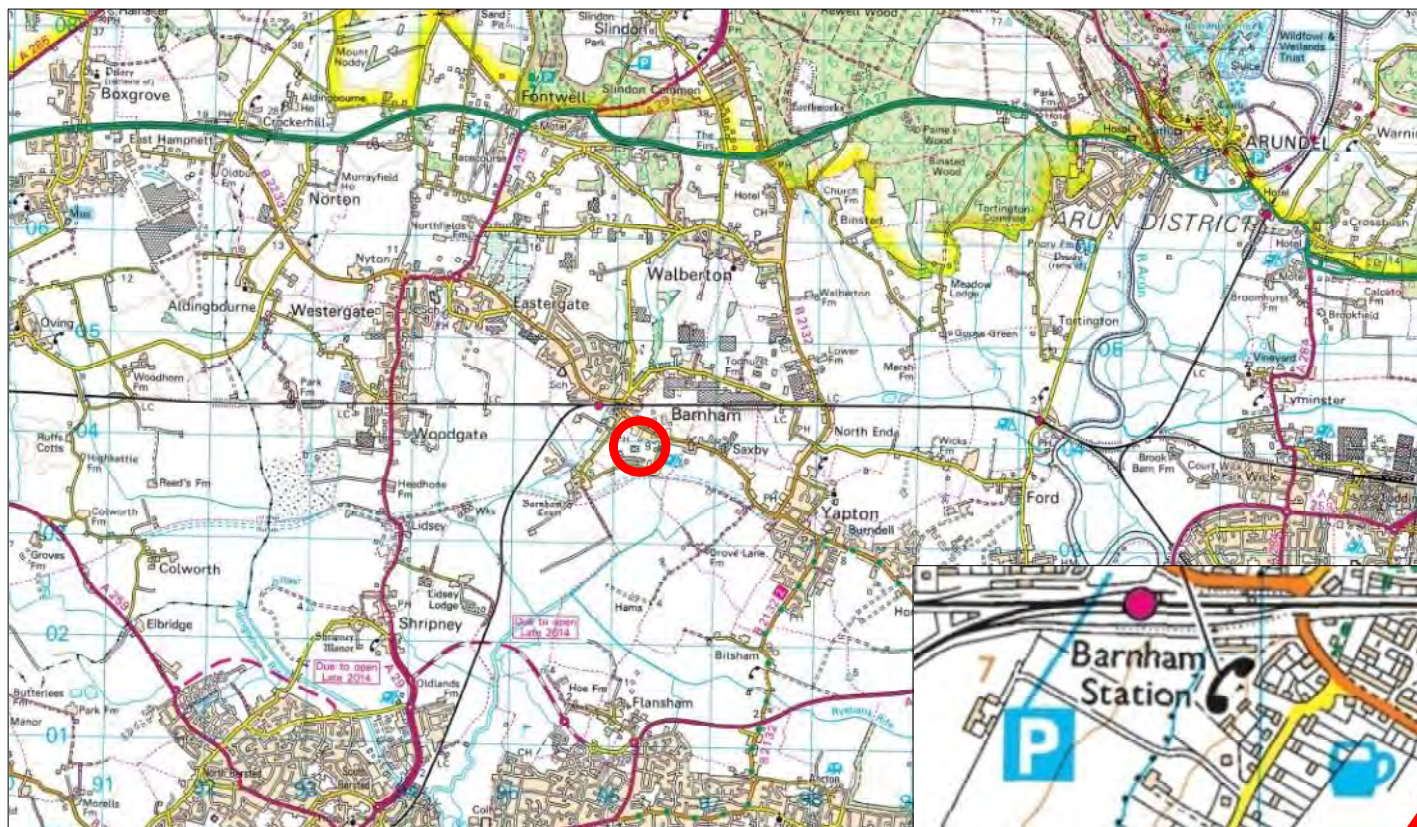
- 11.9.1 On the basis of the shallow groundwater levels recorded at the site, it is considered unlikely that the use of soakaways will be feasible.
- 11.9.2 Additional groundwater monitoring would be recommended in order to determine the likely seasonal maximum.

TWEEDIE EVANS CONSULTING LIMITED

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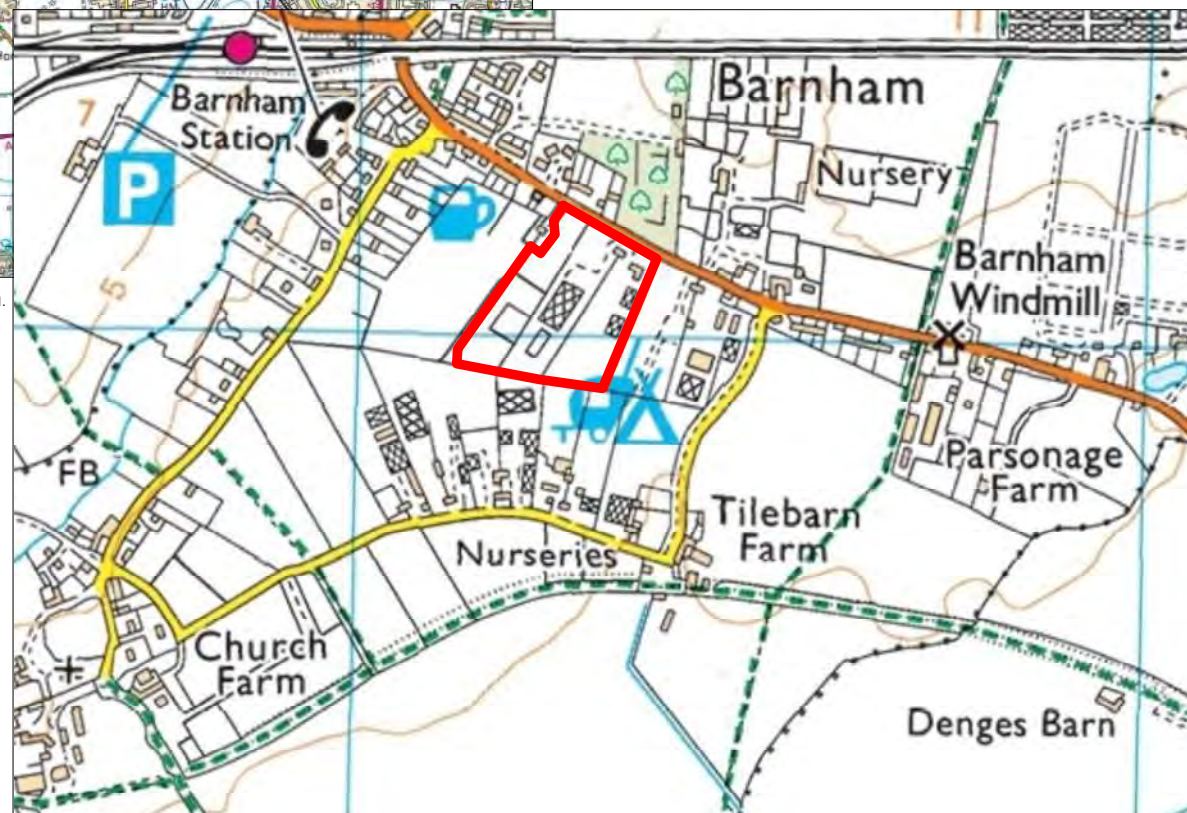
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FIGURES



Approximate Site Location: 

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Tweedie Evans Consulting
The Old Chapel
35a Southover
Wells, Somerset
BA5 1UH

Tel: 01749 677760
Email: info@tecon.co.uk
www.tecon.co.uk

Site Name:
Yapton Road, Barnham

Drawing Name:
Site Location Plan

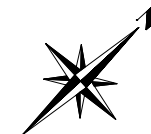
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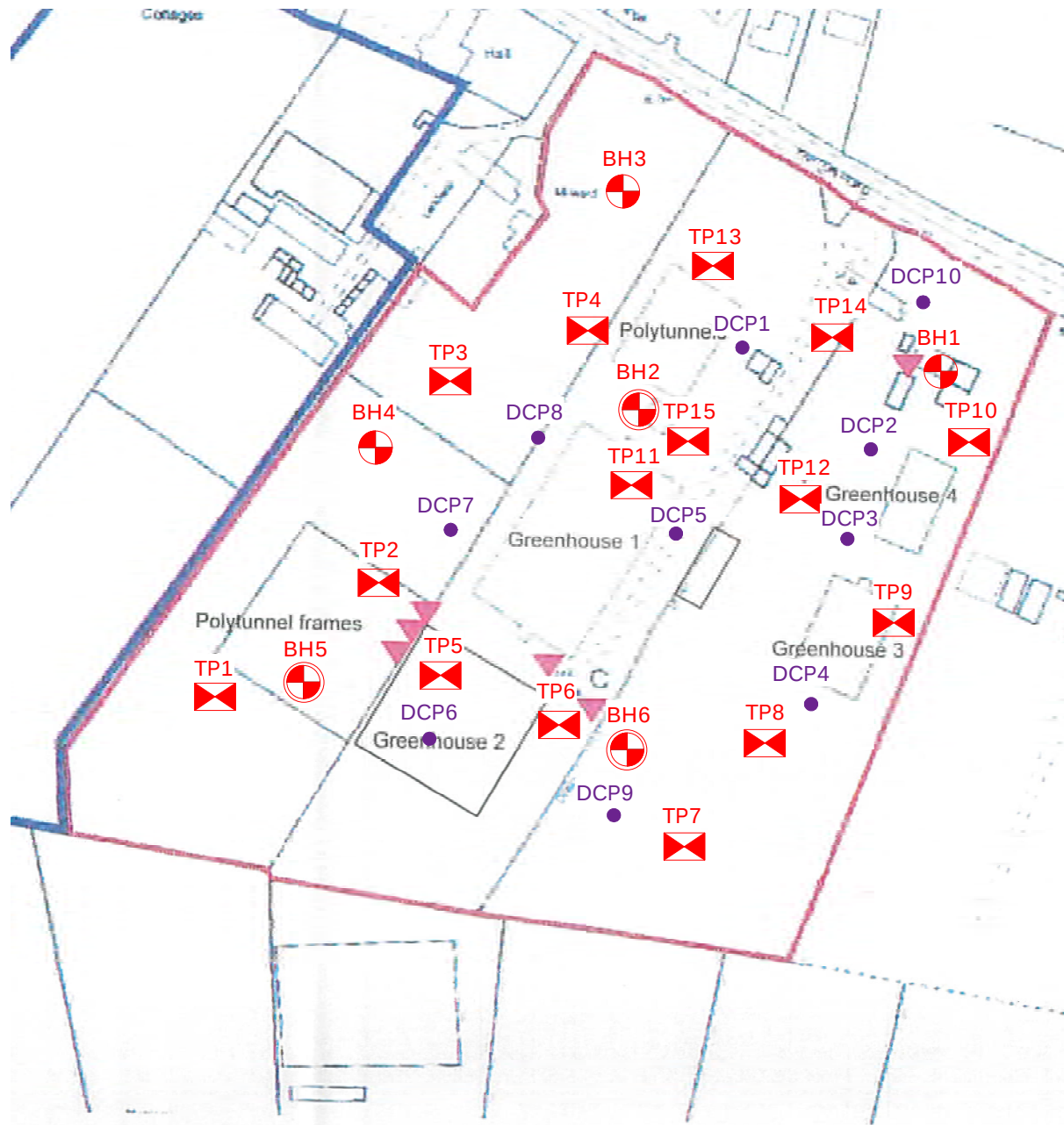
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Date:
April 2018

Scale:
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Extract of Huw Thomas Architects, Angel's Nursery, Barnham
Site Plan showing Public Open Space Areas, Reference 2124/02 Rev A, September 2016



Key

-  TEC Cable Percussive Borehole Location
-  TEC Cable Percussive Borehole Location (with installation)
-  TEC Trial Pit Location
-  TEC DCP-TRL Location

Extract of site plan from Albury S.I. Ltd report (Ref. 09/8848/GO)
Former site layout (2009).

 Albury S.I. Ltd Reported Former Above Ground Storage Tank Location

APPENDIX A

Site Photographs



Photograph 1: View from the southern corner of the site facing north-west.



Photograph 2: View from the southern corner of the site facing north.



Photograph 3: View from the southern corner of the site facing north-east.



Photograph 4: Spoil heap in the northern portion of the site.



Photograph 5: Evidence of potential gas mains along the north-eastern boundary of the site. Now understood to be disconnected from the road.



Photograph 6: View of the entrance to the site off Yapton Road.



Photograph 7: Example of hardstanding associated former site development.



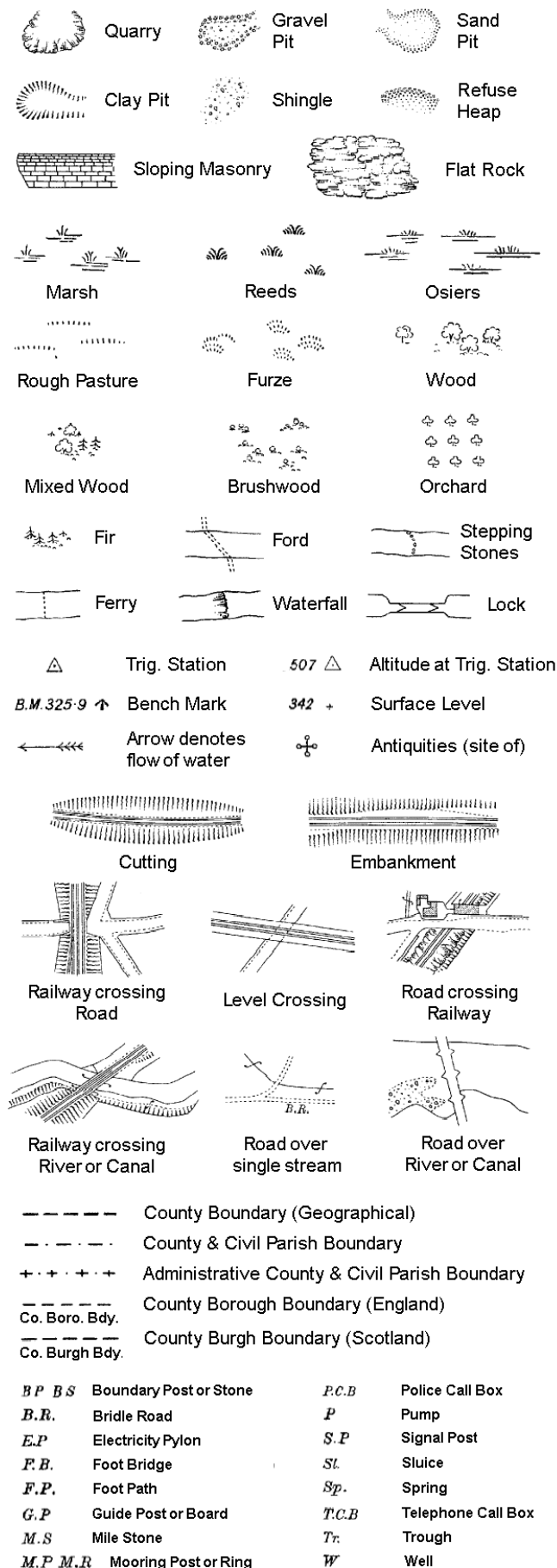
Photograph 8: View of one of the two drainage ditches that run approximately north-east to south-west across the site.

APPENDIX B

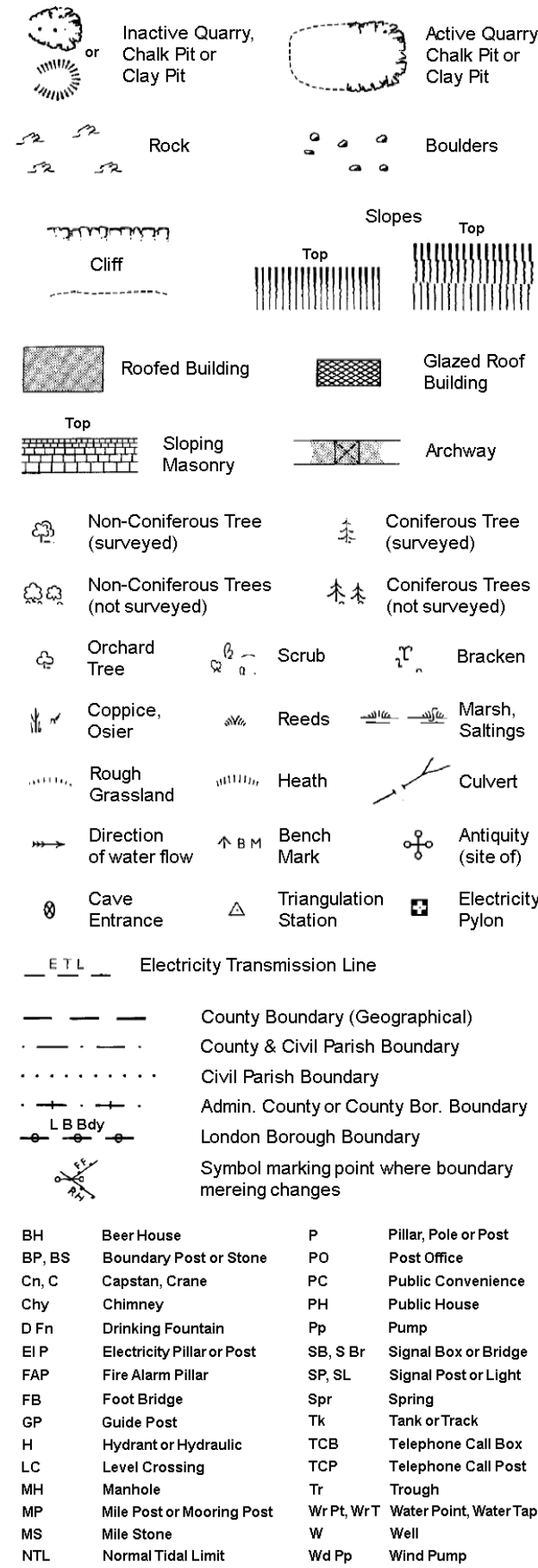
Historical Maps

Historical Mapping Legends

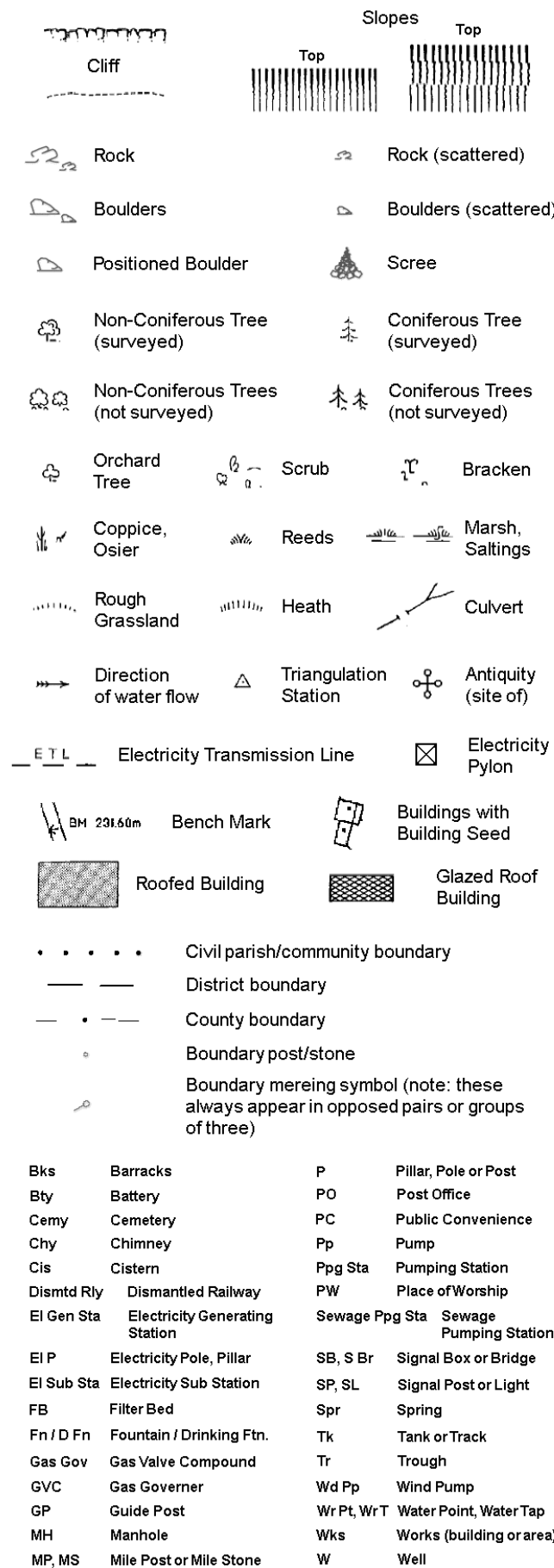
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Ordnance Survey Plan, Additional SIMs and Supply of Unpublished Survey Information 1:2,500 and 1:1,250



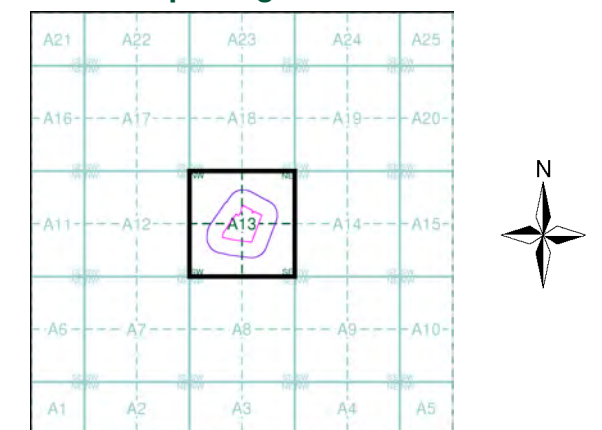
Large-Scale National Grid Data 1:2,500 and 1:1,250



TWEEDIE EVANS CONSULTING
Historical Mapping & Photography included:

Mapping Type	Scale	Date	Pg
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Sussex	1:2,500	1897	3
Sussex	1:2,500	1912	4
Sussex	1:2,500	1938	5
Ordnance Survey Plan	1:2,500	1974 - 1975	6
Supply of Unpublished Survey Information	1:2,500	1975	7
Supply of Unpublished Survey Information	1:2,500	1976	8
Additional SIMs	1:2,500	1978 - 1992	9
Additional SIMs	1:2,500	1980 - 1984	10
Additional SIMs	1:2,500	1983 - 1987	11
Ordnance Survey Plan	1:2,500	1986 - 1989	12
Additional SIMs	1:2,500	1986	13
Large-Scale National Grid Data	1:2,500	1994	14
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Historical Aerial Photography	1:2,500	1999	16

Historical Map - Segment A13



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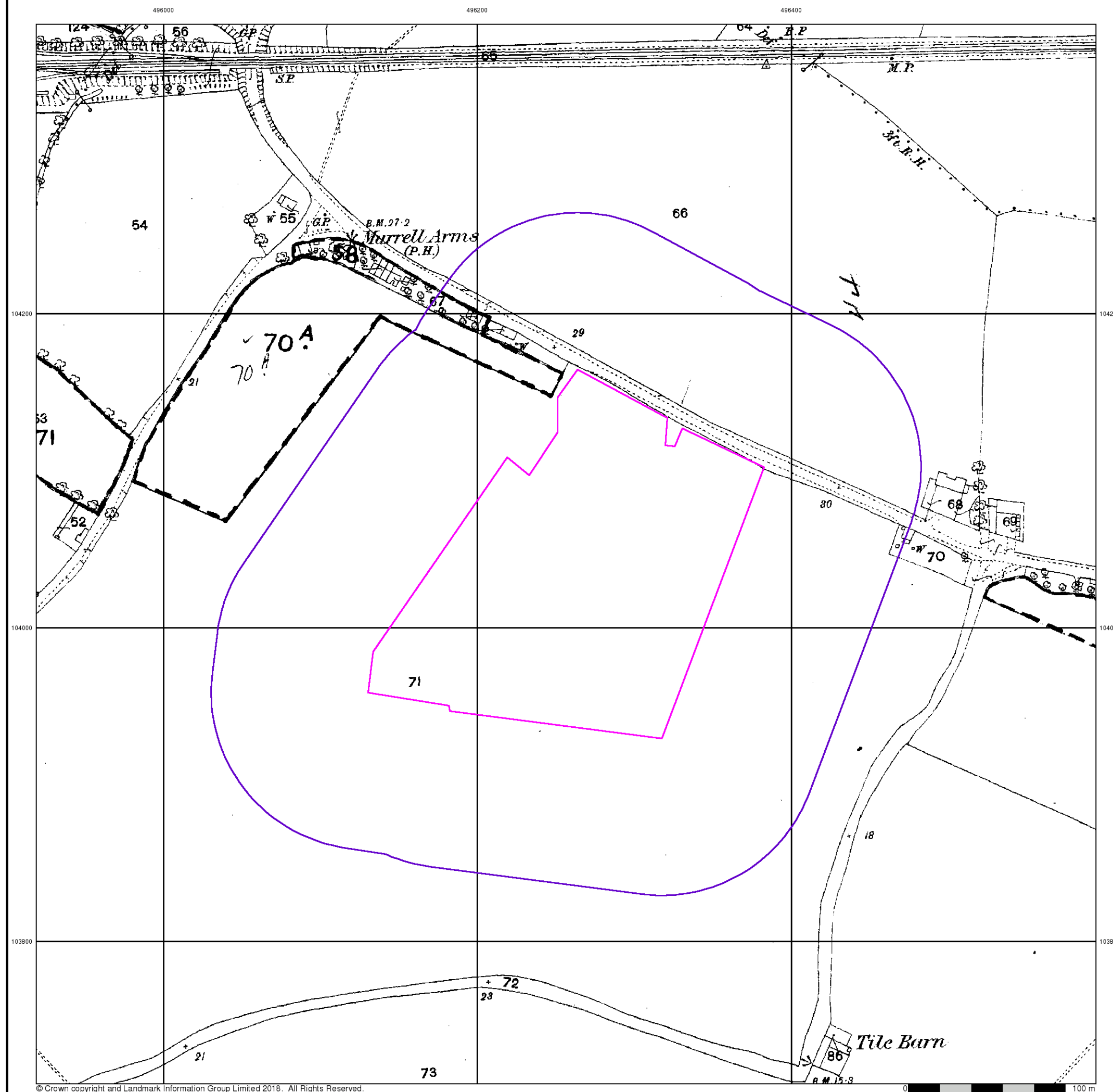
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Search Buffer (m): 100

Site Details

Land off Yapton Road, Barnham, Barnham, BOGNOR REGIS,
PO22 0AY



Tel: 0844 844 9952
Fax: 0844 844 9951
Web: www.envirocheck.co.uk





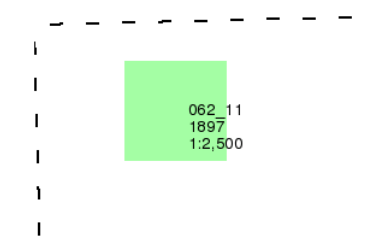
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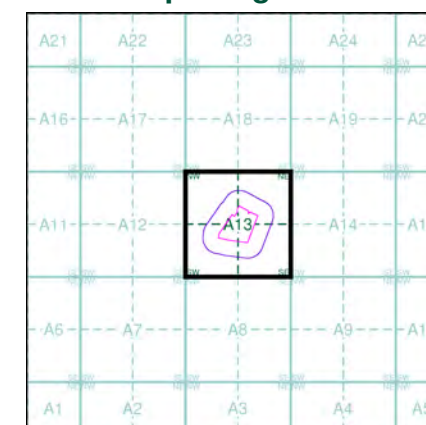
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Map Name(s) and Date(s)



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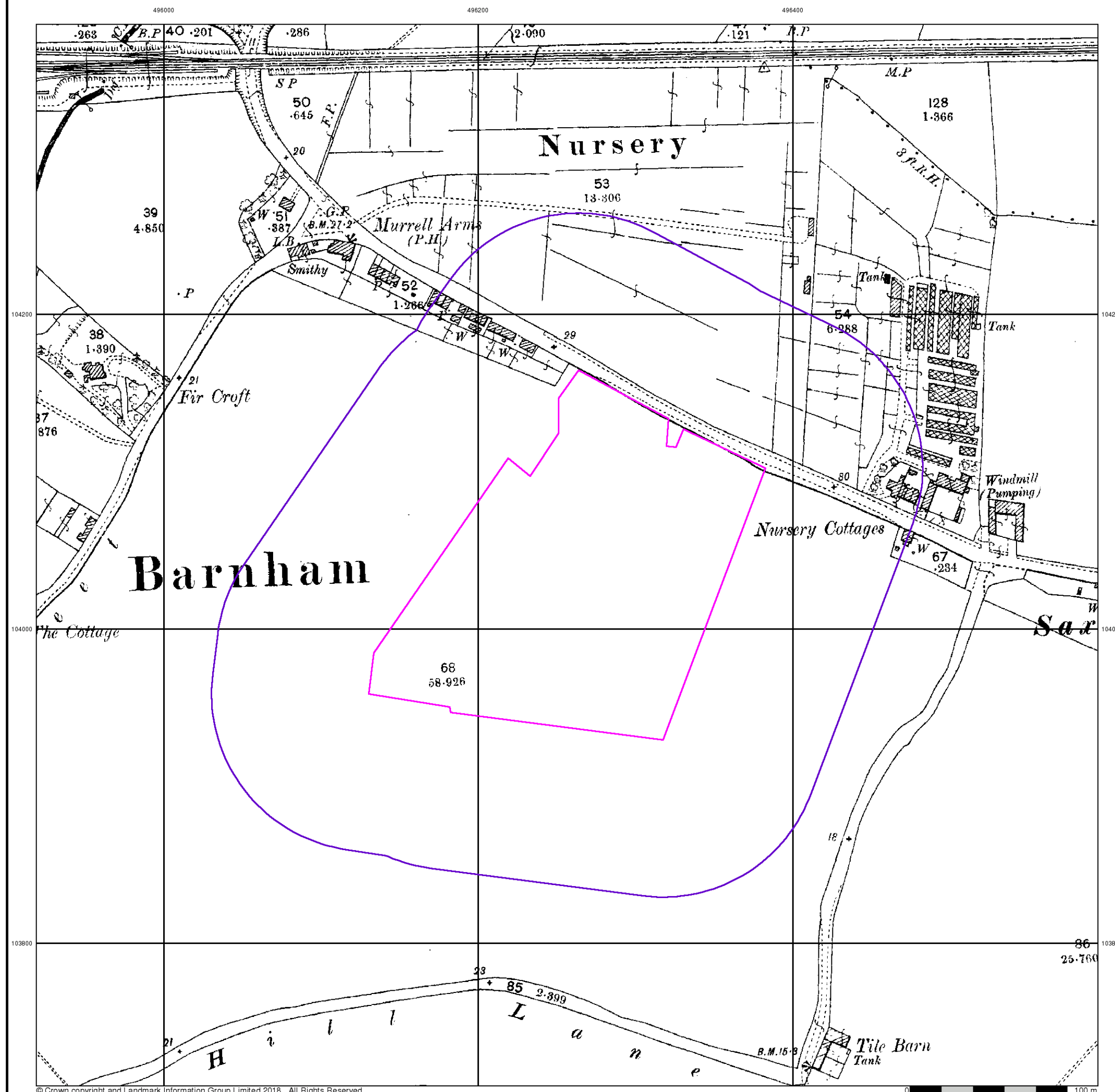
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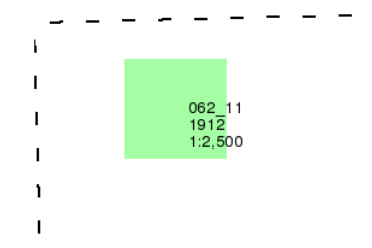
TWEEDIE EVANS CONSULTING
Sussex

Published 1912

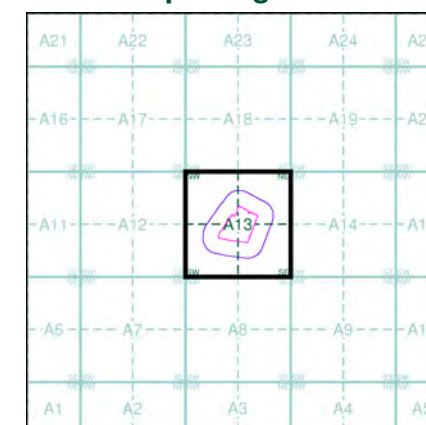
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Map Name(s) and Date(s)



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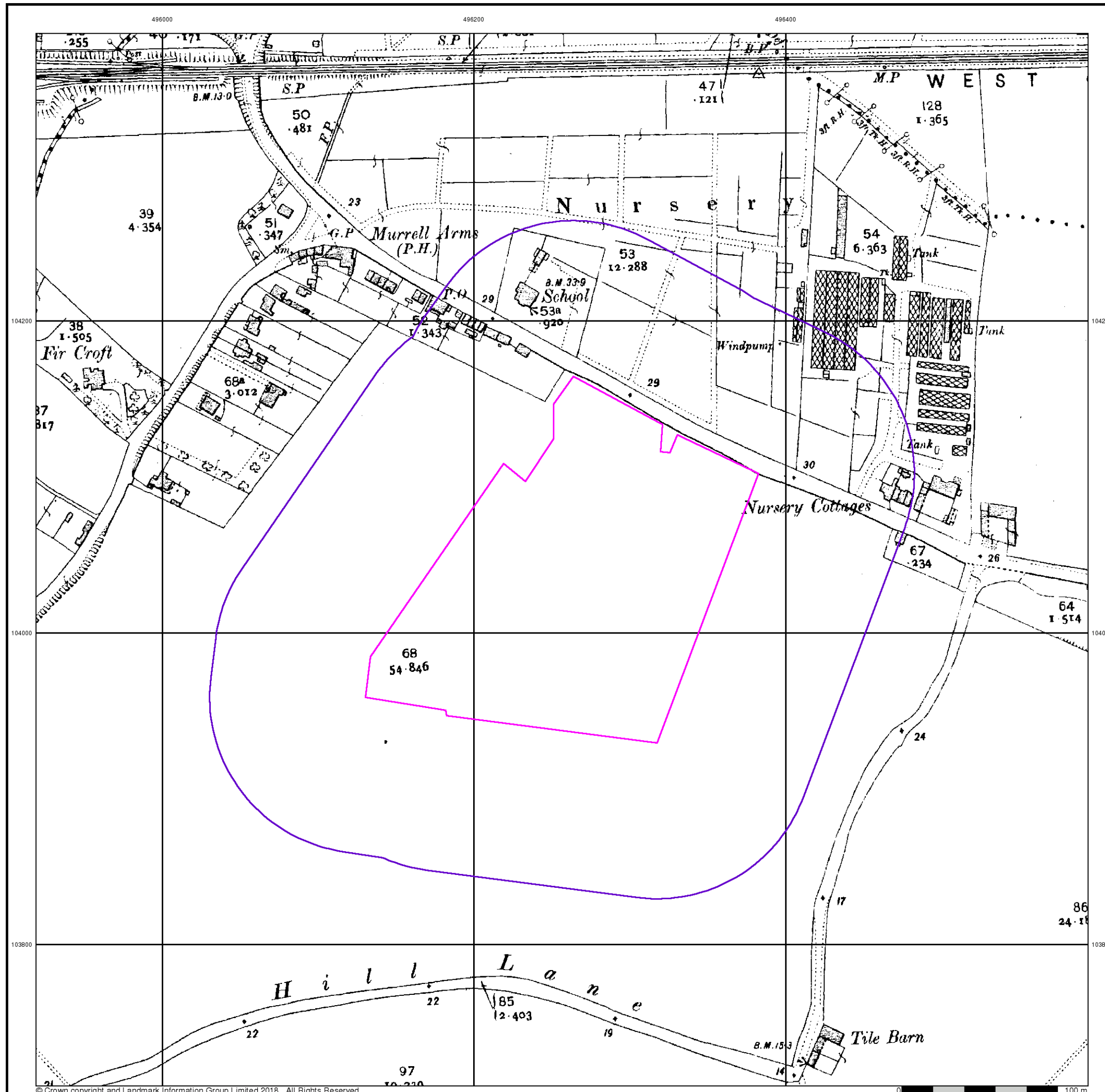
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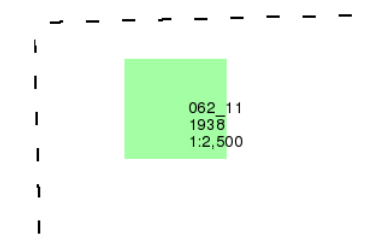
TWEEDIE EVANS CONSULTING
Sussex

Published 1938

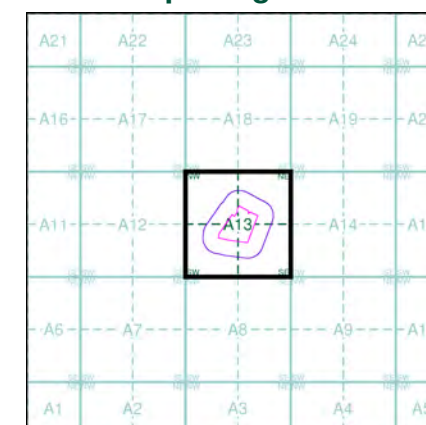
Source map scale - 1:2,500

The historical maps shown were reproduced from maps predominantly held at the scale adopted for England, Wales and Scotland in the 1840's. In 1854 the 1:2,500 scale was adopted for mapping urban areas and by 1896 it covered the whole of what were considered to be the cultivated parts of Great Britain. The published date given below is often some years later than the surveyed date. Before 1938, all OS maps were based on the Cassini Projection, with independent surveys of a single county or group of counties, giving rise to significant inaccuracies in outlying areas.

Map Name(s) and Date(s)



Historical Map - Segment A13



Order Details

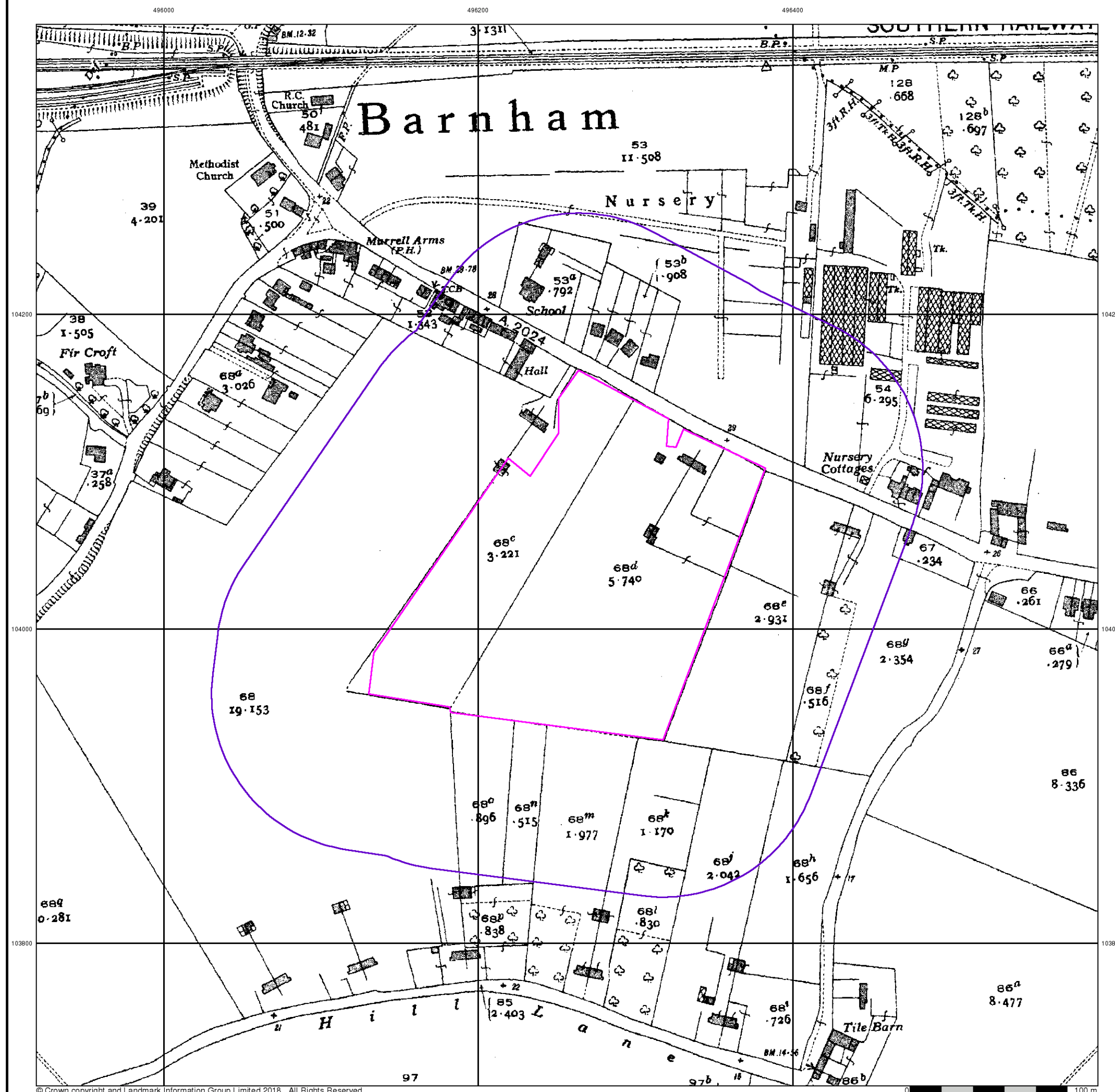
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Customer Ref: 1801024.001
National Grid Reference: 496260, 104030
Slice: A
Site Area (Ha): 3.46
Search Buffer (m): 100

Site Details

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Ordnance Survey Plan

Published 1974 - 1975

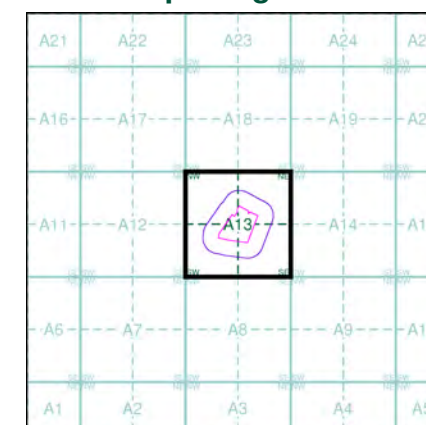
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The historical maps shown were reproduced from maps predominantly held at the scale adopted for England, Wales and Scotland in the 1840's. In 1854 the 1:2,500 scale was adopted for mapping urban areas and by 1896 it covered the whole of what were considered to be the cultivated parts of Great Britain. The published date given below is often some years later than the surveyed date. Before 1938, all OS maps were based on the Cassini Projection, with independent surveys of a single county or group of counties, giving rise to significant inaccuracies in outlying areas.

Map Name(s) and Date(s)

SU9504 1974 12,500	SU9604 1975 12,500
SU9503 1974 12,500	SU9603 1975 12,500

Historical Map - Segment A13



Order Details

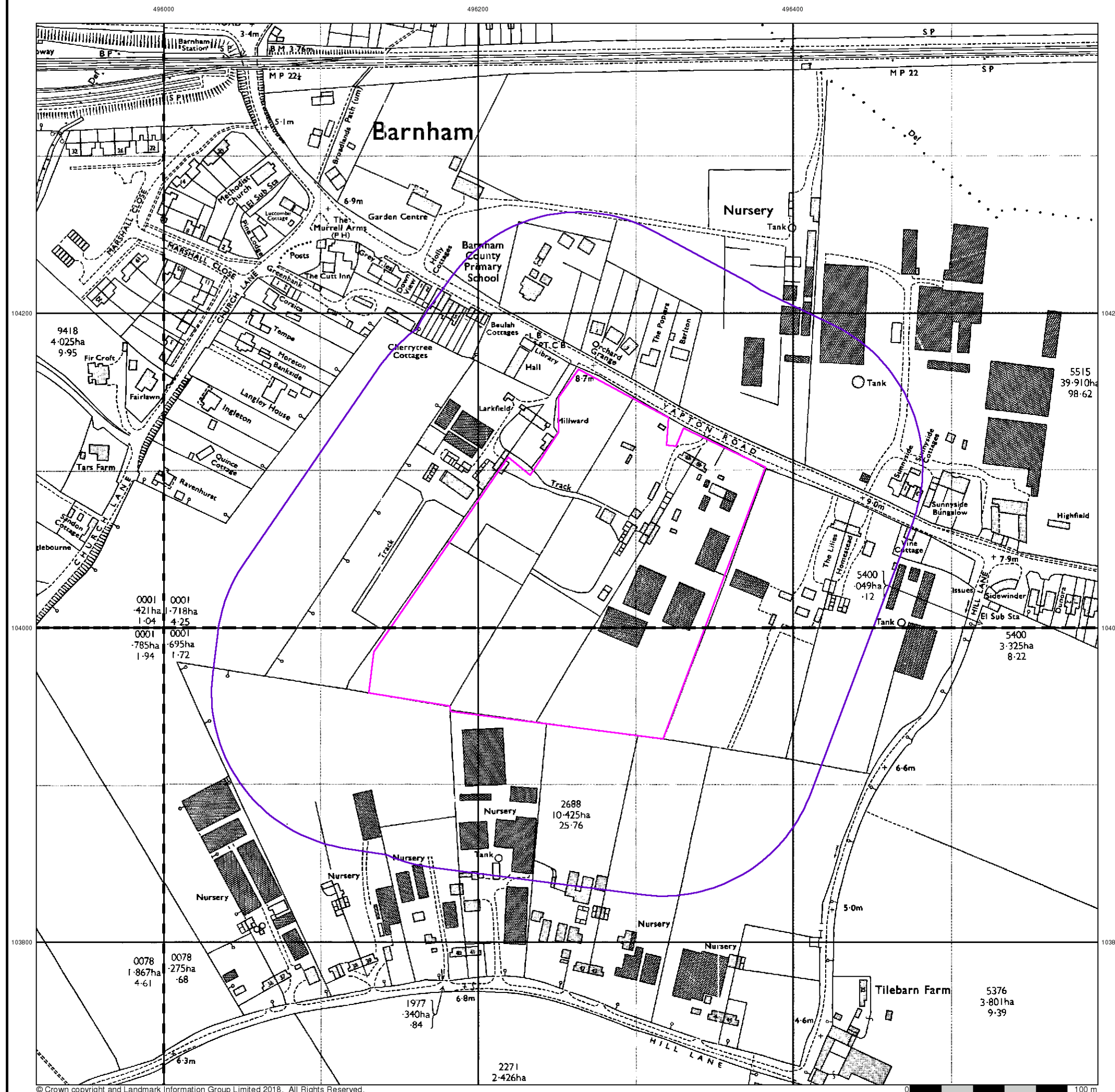
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Supply of Unpublished Survey
Information

Published 1975

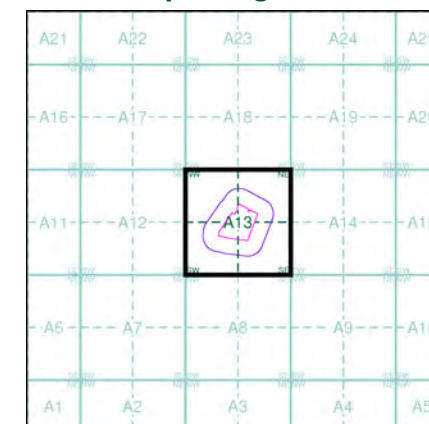
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SUSI maps (Supply of Unpublished Survey Information) were produced between 1972 and 1977, mainly for internal use at Ordnance Survey. These were more of a 'work-in-progress' plan as they showed updates of individual areas on a map. These maps were unpublished, and they do not represent a single moment in time. They were produced at both 1:2,500 and 1:1,250 scales.

Map Name(s) and Date(s)

SU9504 1975 1:2,500	SU9604 1975 1:2,500
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Historical Map - Segment A13



Order Details

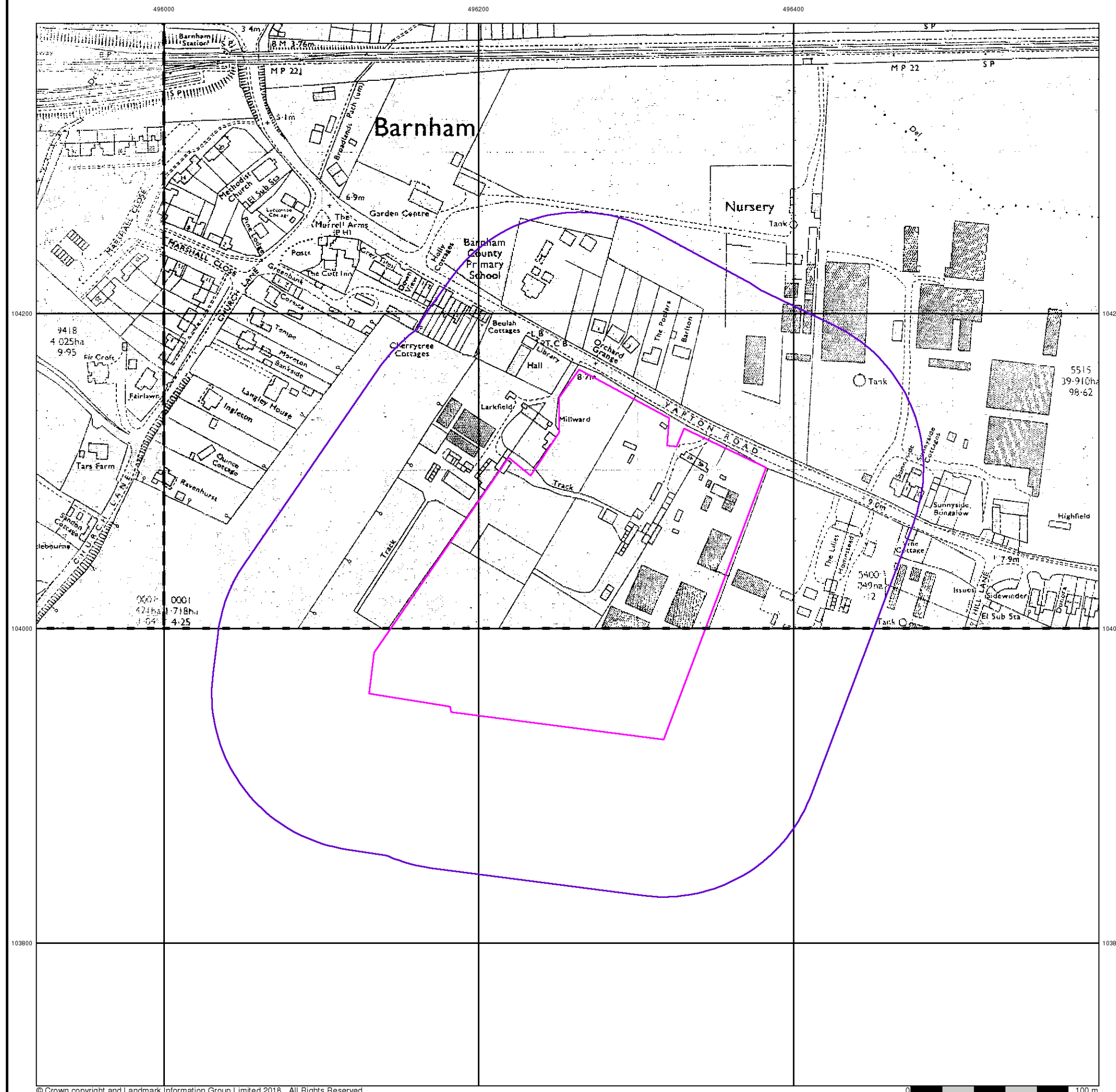
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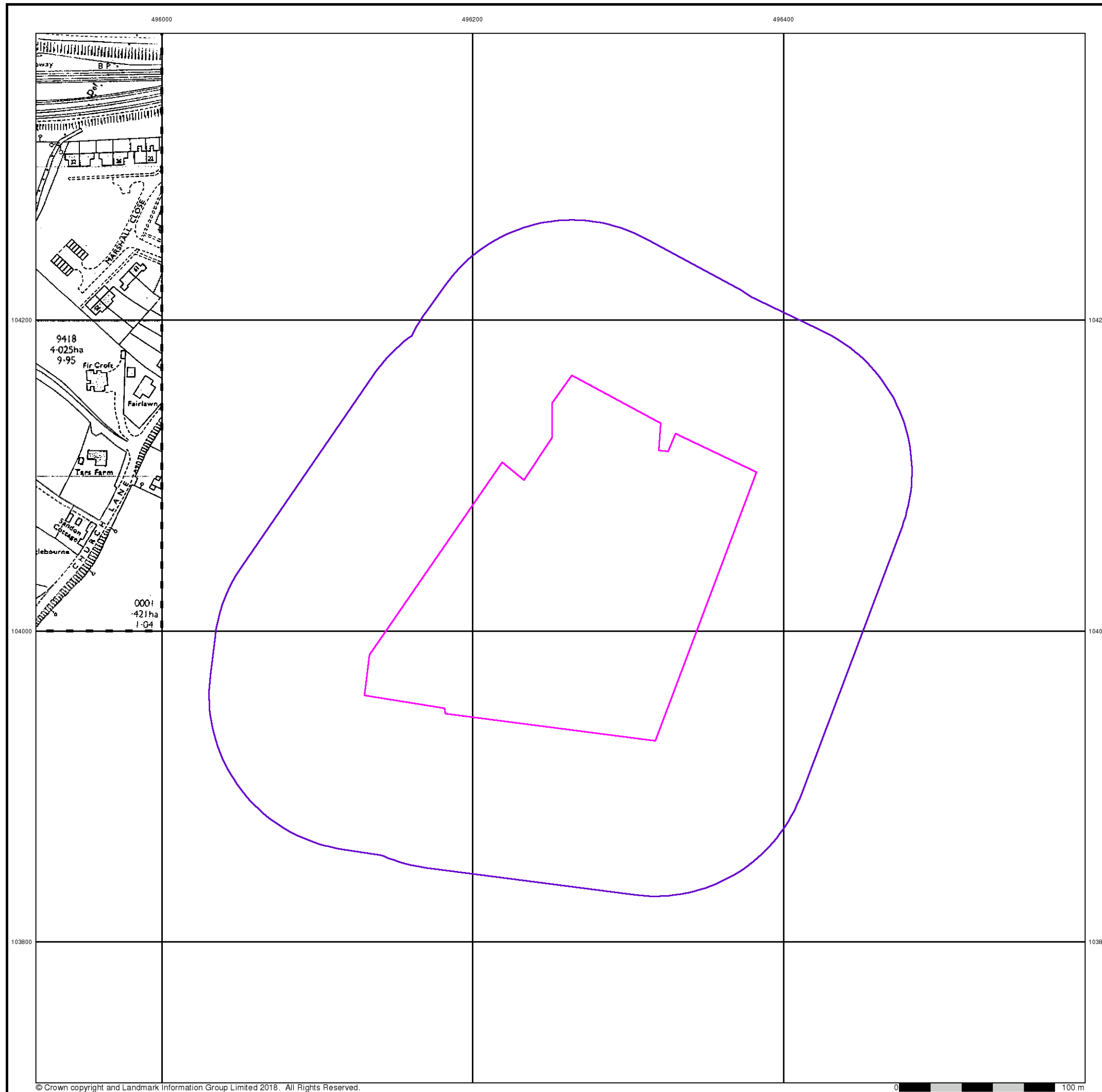
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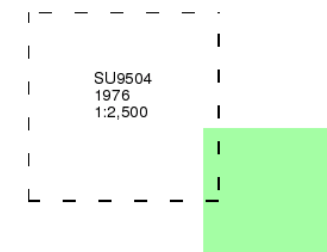
TWEEDIE EVANS CONSULTING
Supply of Unpublished Survey
Information

Published 1976

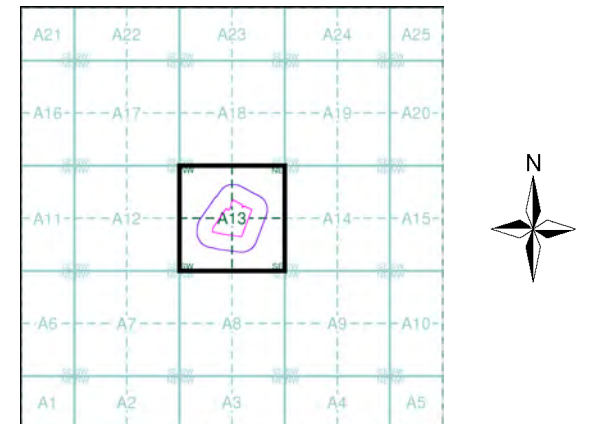
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Map Name(s) and Date(s)



Historical Map - Segment A13



Order Details

Order Number: 163503061_1_1
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Additional SIMs

Published 1980 - 1984

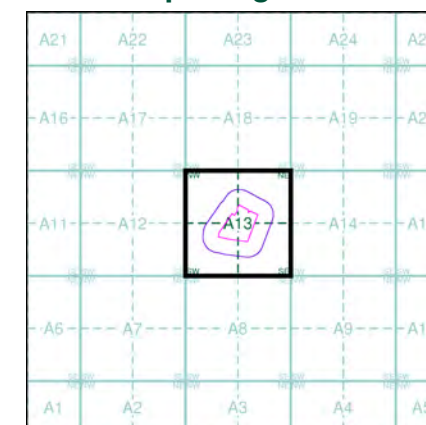
Source map scale - 1:2,500

The SIM cards (Ordnance Survey's 'Survey of Information on Microfilm') are further, minor editions of mapping which were produced and published in between the main editions as an area was updated. They date from 1947 to 1994, and contain detailed information on buildings, roads and land-use. These maps were produced at both 1:2,500 and 1:1,250 scales.

Map Name(s) and Date(s)

SU9504 1980 1:2,500	SU9604 1984 1:2,500
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Historical Map - Segment A13



Order Details

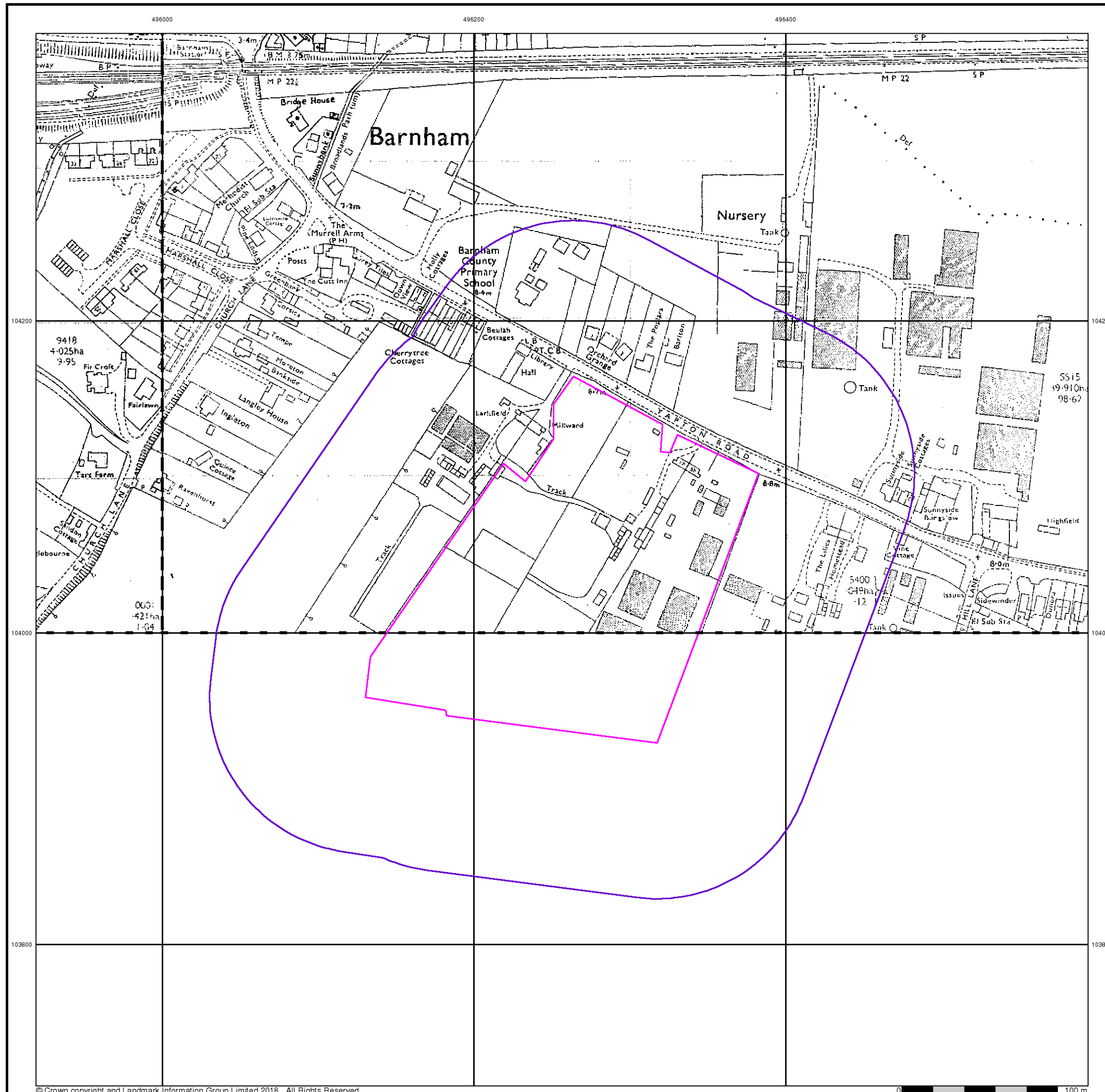
Order Number: 163503061_1_1
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Additional SIMs

Published 1983 - 1987

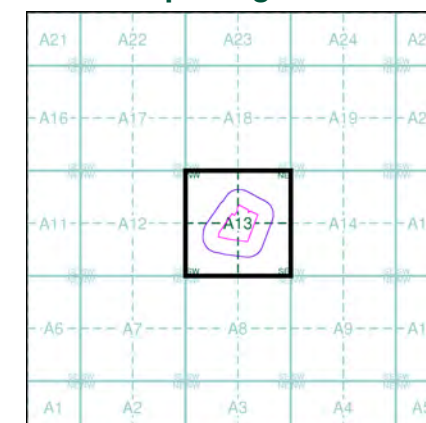
Source map scale - 1:2,500

The SIM cards (Ordnance Survey's 'Survey of Information on Microfilm') are further, minor editions of mapping which were produced and published in between the main editions as an area was updated. They date from 1947 to 1994, and contain detailed information on buildings, roads and land-use. These maps were produced at both 1:2,500 and 1:1,250 scales.

Map Name(s) and Date(s)

SU9504 1983 1:2,500	SU9604 1987 1:2,500
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Historical Map - Segment A13



Order Details

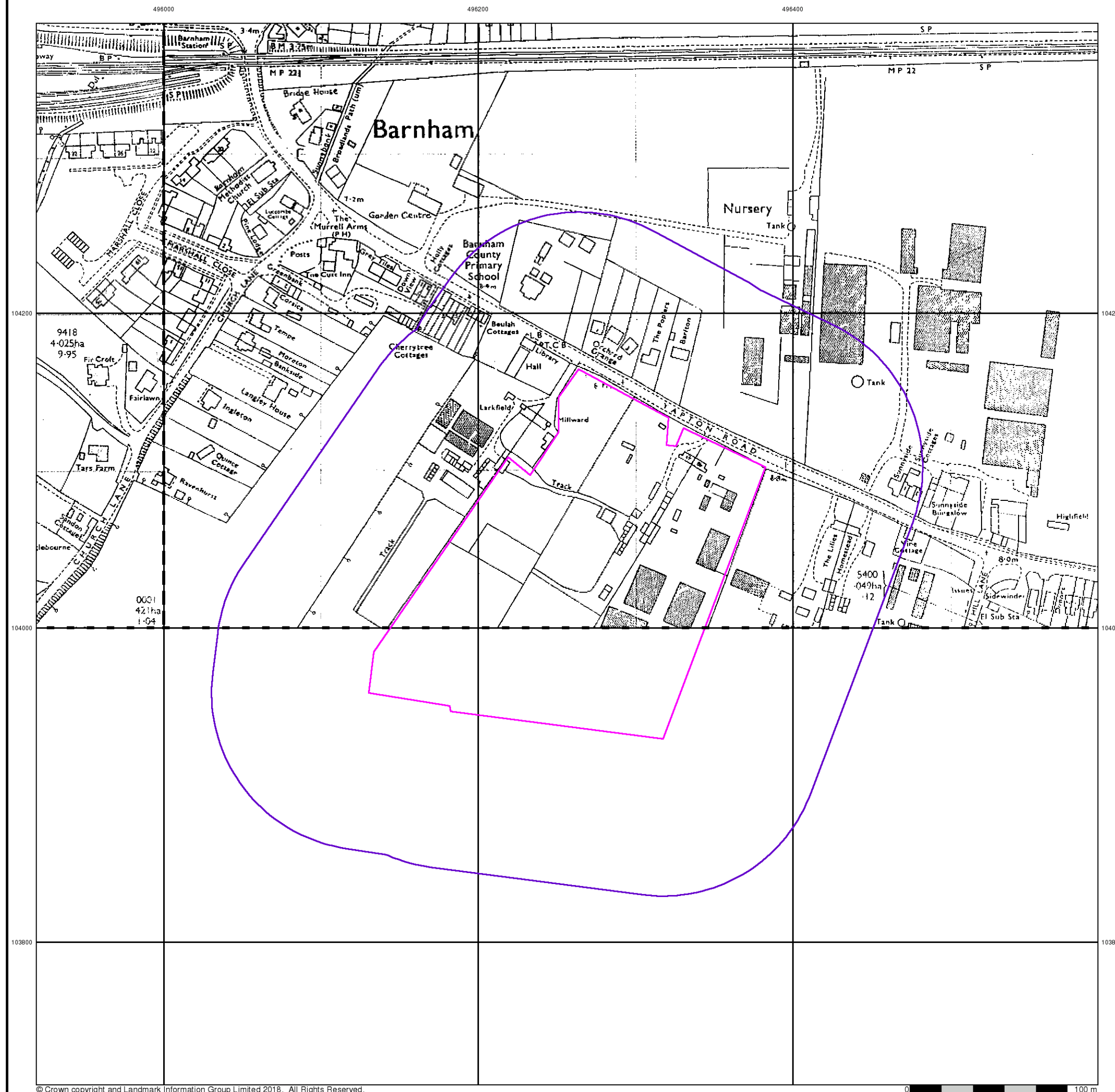
Order Number: 163503061_1_1
Customer Ref: 1801024.001
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Ordnance Survey Plan

Published 1986 - 1989

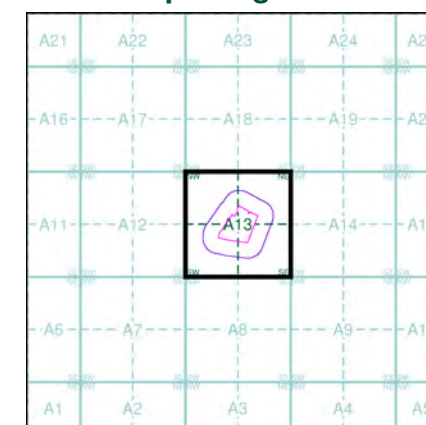
Source map scale - 1:2,500

The historical maps shown were reproduced from maps predominantly held at the scale adopted for England, Wales and Scotland in the 1840's. In 1854 the 1:2,500 scale was adopted for mapping urban areas and by 1896 it covered the whole of what were considered to be the cultivated parts of Great Britain. The published date given below is often some years later than the surveyed date. Before 1938, all OS maps were based on the Cassini Projection, with independent surveys of a single county or group of counties, giving rise to significant inaccuracies in outlying areas.

Map Name(s) and Date(s)

SU9504 1986 1:2,500	SU9604 1989 1:2,500
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Historical Map - Segment A13



Order Details

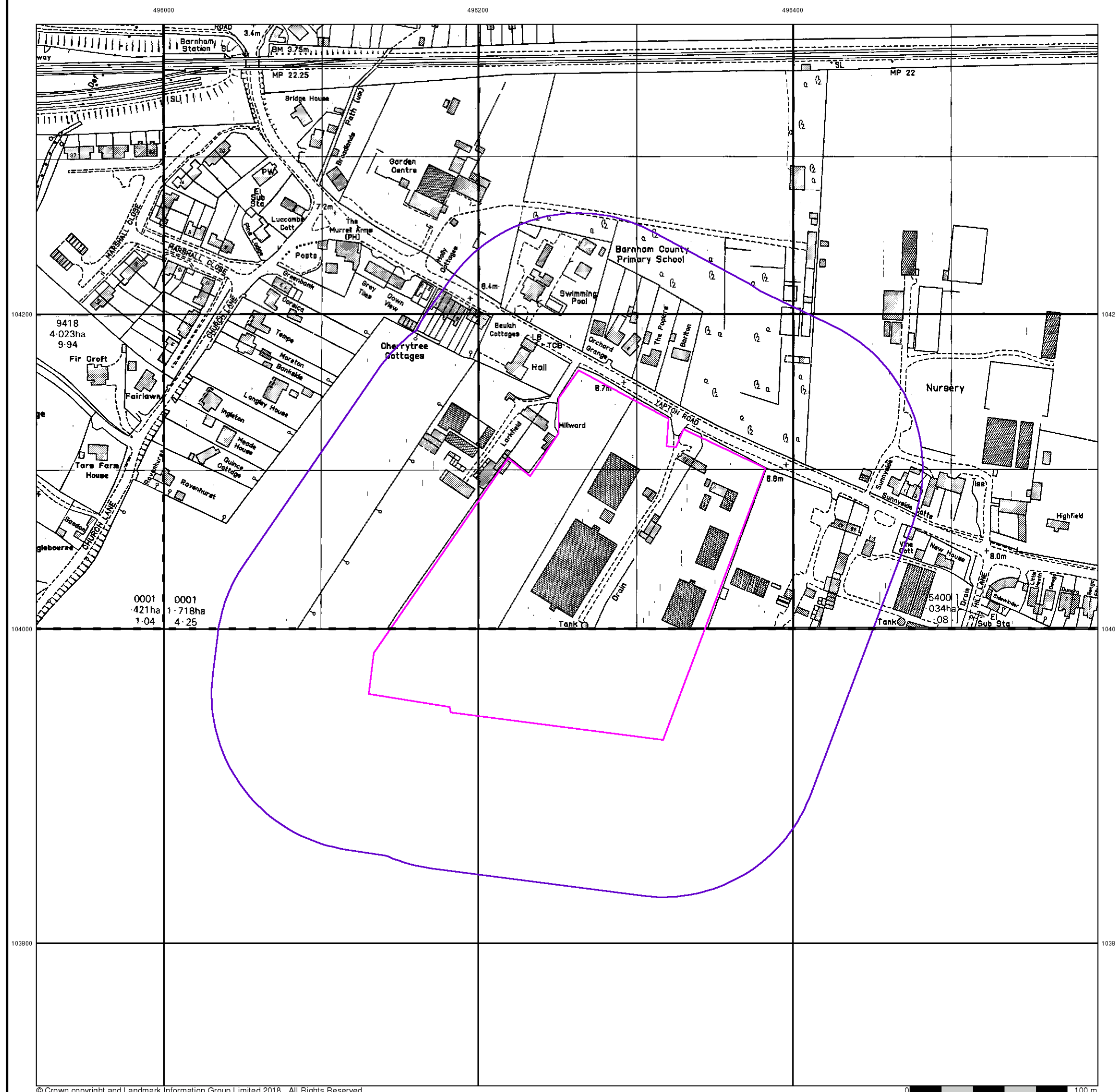
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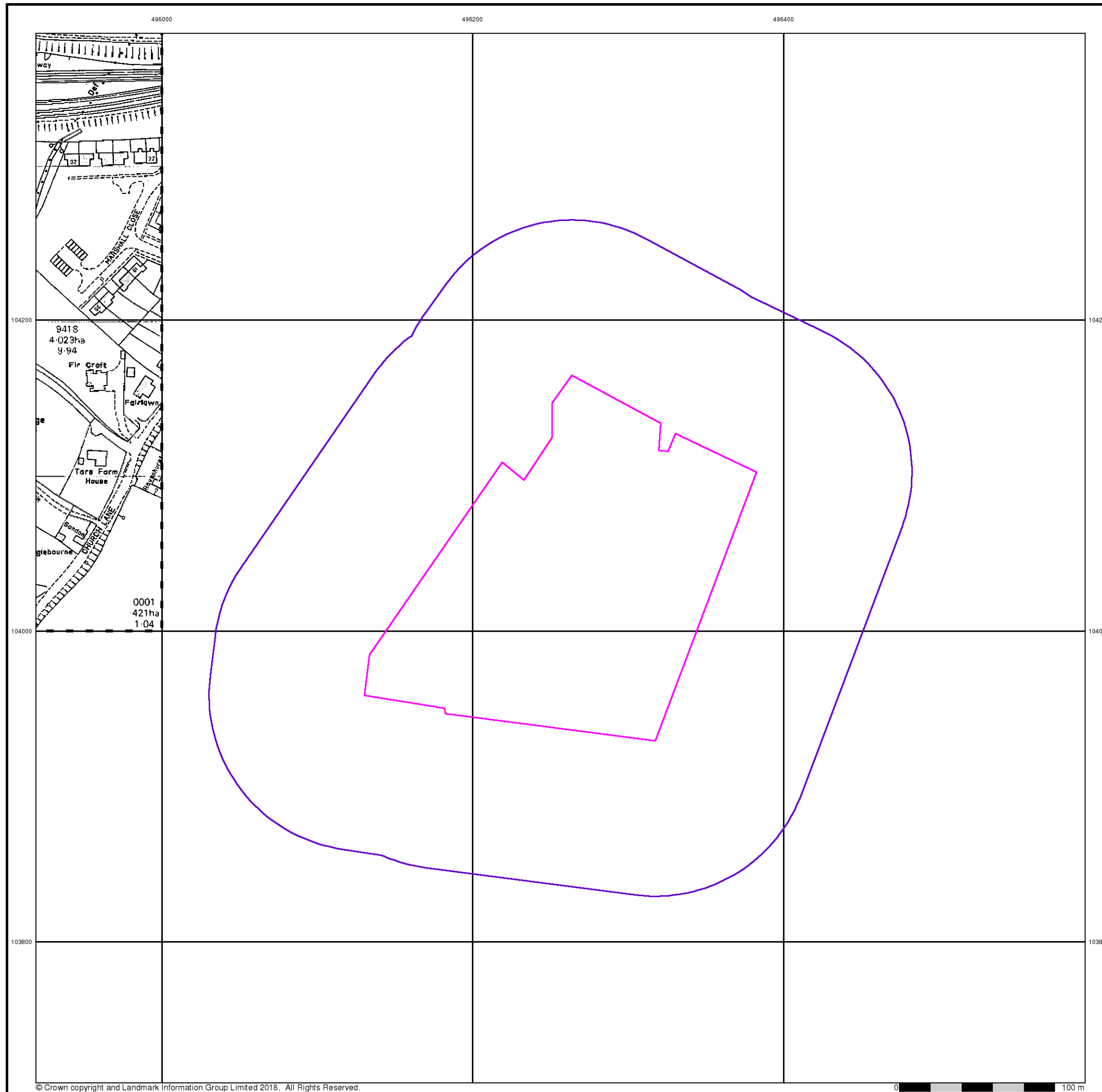
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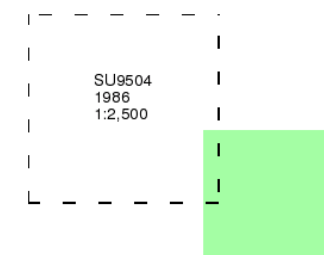
Additional SIMs

Published 1986

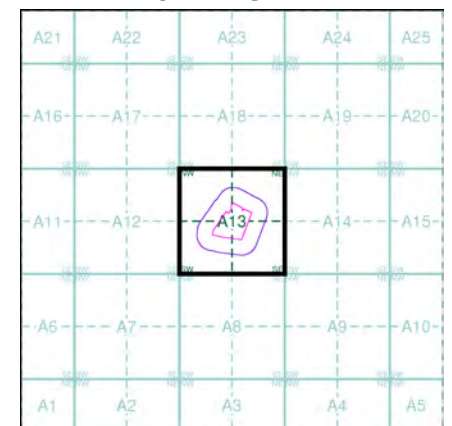
Source map scale - 1:2,500

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Map Name(s) and Date(s)



Historical Map - Segment A13



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