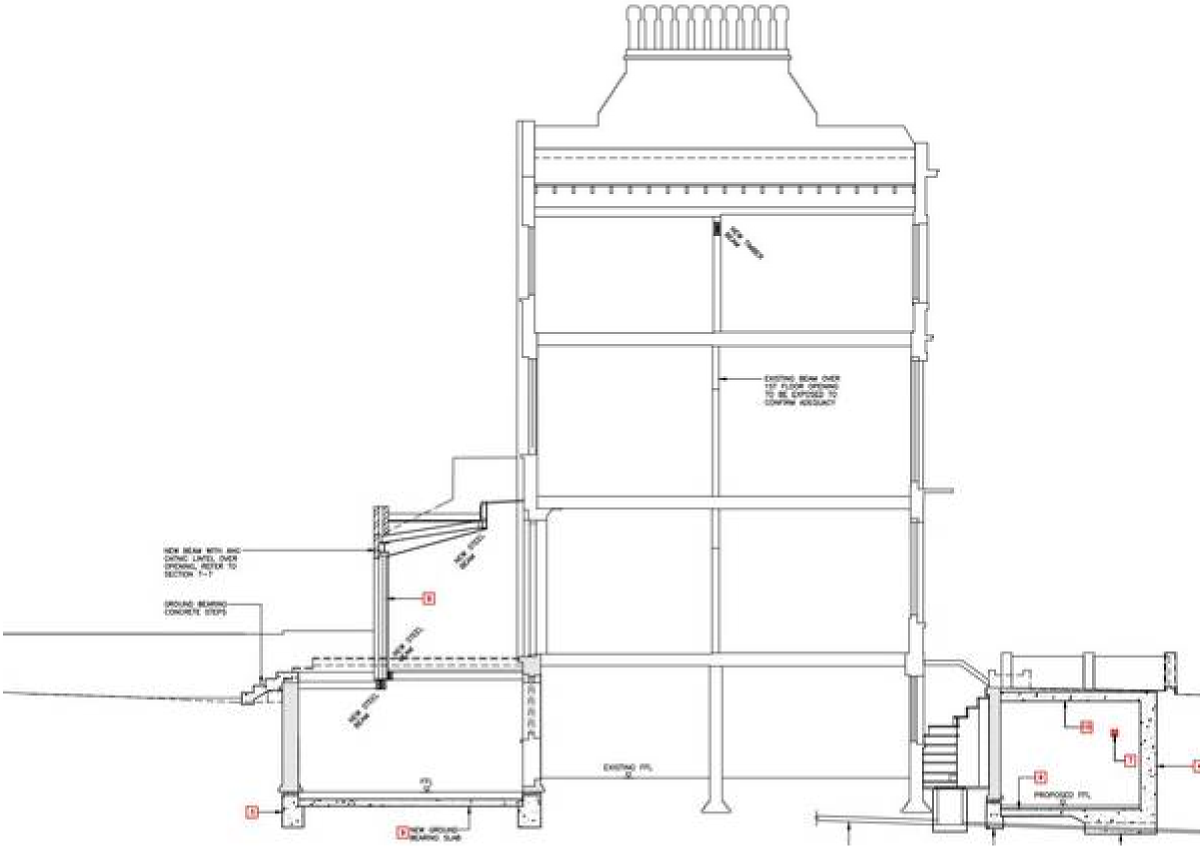

LMB GEOSOLUTIONS LTD

GROUND MOVEMENT ASSESSMENT

47 ALBERT ST, LONDON NW1

January 2017

DOCUMENT RECORD

Document Title	Ground Movement Assessment
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Document Authorisation	Philip Lewis BSc (Hons), MSc, CGeol, FGS P. L. THE GEOLOGICAL SOCIETY CGeol CHARTERED GEOLOGIST Fellow No. 1012476

Ground Investigation
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INTRODUCTION

Introduction

AUTHORISATION

LMB Geosolutions Ltd (LMB) was instructed Symmetrys Ltd (Consultant Engineers) on behalf of Mr Neil and Mrs Angela Moran (the Client) in December 2016 to undertake a Ground Movement Assessment in relation to the proposed basement development at 47 Albert Street, London NW1 7LX (the Site).

PROJECT AND SITE DETAILS

Site Address	47 Albert Street, London NW1 7LX. A Site Location Plan is provided as **Figure 1**.
Proposed Development	The site comprises a four storey (including lower ground floor) residential terrace property. It is understood that the Client wishes to construct an extension to the existing lower ground floor of the property.
Existing Reports	LMB has previously produced the following report in relation to the proposed development: • LMB (ref. LMB.16.12.16_RIPPIL_Albert_St_v2.0, dated 16th December 2016). Ground Investigation & Assessment. 47 Albert Street, London NW1. The report includes a Preliminary Risk Assessment (PRA) and the results and findings from ground investigation works completed at the site to aid in development design.

AIMS & OBJECTIVES

This assessment aims to use information from the existing ground investigation and details of the development proposals to undertake a Ground Movement Assessment (GMA) that will estimate the potential impact of the proposed basement development on surrounding buildings / structures.

SCOPE OF WORKS

The following scope of works has been completed:

- Review of available architects plans for the site and surrounding properties to understand the dimensions of neighbouring / adjacent structures and any existing basements. It has been assumed that this information is available and no costs/fees have been allocated to producing such drawings / information;
- Review of the RBKC planning portal to acquire any information in relation to existing / planned neighbouring basements;

INTRODUCTION

- Review of data from the recent ground investigation to appraise ground conditions and potential foundation options;
- Completion of GMA calculations in accordance with the CIRIA publication C580 Embedded Retaining Walls – Guidance for Economic Design;
- Provision of an interpretive report that:
  - Summarises any assumptions and findings;
  - Provides estimates of any predicted damage/impact based upon the Burland scale; and
  - Provides recommendations for additional works and/or mitigation measures.

CONTRIBUTORS

This report has been compiled by Philip Lewis a hydrogeologist and chartered Geologist with over nineteen years experience as a geoscience professional, including over fifteen years experience as a professional adviser (consultant) in hydrogeology, engineering geology and contaminated land.

The Ground Movement Assessment has been completed by Corrado Candian (CEng, MICE).

LIMITATIONS

LMB has prepared this report solely for the use of the named Client and those parties with whom a warranty agreement and/or assignment has been agreed. Should any third party wish to use or rely upon the contents of the report, written approval must be sought from LMB and the Client.

LMB accepts no responsibility or liability for:

a) the consequences of this document being used for any purpose or project other than for which it was commissioned, and

b) issue of this document to any third party with whom an agreement has not been executed.

The risk assessment and opinions provided, among other things, take in to consideration currently available guidance and best available techniques relating to acceptable contamination concentrations and interpretation of these values. No liability can be accepted for the retrospective effects of any future changes or amendments to these value.

SUMMARY OF GROUND CONDITIONS

Summary of Ground Conditions

INTRODUCTION

The ground investigation works were undertaken on 18th July 2016 and comprised the progression of a dynamic (windowless) sampler borehole to 8.35m bgl and excavation of 4no. hand excavated trial pits with sampling of soil for laboratory testing (see **Figure 2**).

Groundwater monitoring was undertaken following completion of the fieldworks on 28th July 2016.

Details of the ground investigation completed, along with the findings of the investigation, are provided in the Ground Investigation and Assessment report (ref. LMB.16.12.16_RIPPIL_Albert_St_v2.0, dated 16th December 2016).

GROUND & GROUNDWATER CONDITIONS

Ground Conditions

The table below provides a summary of ground conditions encountered with full descriptions provided in the associated exploratory hole logs provided in the Ground Investigation and Assessment report (ref. LMB.16.12.16_RIPPIL_Albert_St_v2.0, dated 16th December 2016).

Strata	Depth Range to Top (m bgl)	Depth Range to (Base (m bgl)	Summary Description
Made Ground	Ground Level	0.45 – 1.70	In the trial pit locations, the ground surface was generally found to comprise concrete. In BH1 (front garden) the ground surface comprised floor pavers over concrete screed. The Made Ground soils were generally found to comprise locally gravelly and sandy clay with varying proportions of brick and concrete.
London Clay Formation	0.45 – 1.70	8.35(1)	The London Clay was found to comprise an upper sequence (c.0.5m) of soft clay overlying firm becoming stiff very closely fissured clay.

(1) Base of the London Clay was not determined.

Groundwater Conditions

No groundwater strikes were recorded during the ground investigation works. During the return monitoring visit completed on 29th July 2016 no groundwater was recorded to the base of the monitoring well at 6.00m bgl.

SUMMARY OF GROUND CONDITIONS

Characteristic Values of Soil Parameters

A summary of the geotechnical properties of the strata based on the field and laboratory testing is provided in the table below.

Soil Property	Stratum	
	Made Ground	London Clay
SPT 'N' Value	6	9 – 39
Bulk Density (mg/m^3)	1.70(2)	1.83 – 2.35 (1)
Moisture Content (%)	18 – 31	29 – 32
Plasticity Index (%)	-	45 – 47
pH	8.1 – 8.3	8.3
Sulphate (g/l)	0.026	0.13

(1) Literature values taken from Forster (1997)

(2) Value based on BS8002

Summary of Foundation Options

INTRODUCTION

It is understood that the development will comprise an extension to the existing lower ground floor of the property. On this basis, it the following assumptions have been made:

- The formation level for the floor of the extension will be at approximately 3.0m bgl;
- The load from the existing four storey structure will be in the region of 40-60KN/m^2 which is not anticipated to significantly alter following the extension. No additional loads are envisaged;
- For a four storey structure (including the roof) the existing wall load is estimated at approximately 80-100kN/m run, which is not anticipated to significantly alter following basement deepening and extension.
- There will be no significant changes in elevation over the proposed basement development.
- Foundations will not be eccentrically loaded.

FOUNDATION OPTIONS

Spread Foundations

Based on the findings of the ground investigation and the subsequent laboratory testing it has been concluded that for traditional spread foundations (placed on the competent firm London Clay) at the assumed formation level of 3.0m bgl a net safe bearing pressure of 85kN/m^2 should be available.

It is recommended that the undrained shear strength of soils at formation level be confirmed using a hand shear vane and should exceed 40kN/m^2.

Should formation level be extended to 4.0m bgl a net safe bearing pressure of 120kN/m^2 should be available. In this case, it is recommended that the undrained shear strength of soils at formation level be confirmed using a hand shear vane and should exceed 50kN/m^2.

The bearing pressure is based on a factor of safety of 3 to ensure that settlement remains within normally acceptable limits.

The above advice assumes that the proposed basement development and in particular foundations would not be within the influence of any trees or tree routes.

The Consultant Engineers have confirmed that the basement formation level will be approximately 3.0m bgl.

Piled Foundations

Based on the proposed development and the ground conditions encountered it is considered unlikely that a piled foundation would be the most feasible solution. However, it is possible that sheet piling may be considered as part of the temporary works.

Ground Movement

INTRODUCTION

As outline, the site comprises a four storey (including lower ground floor) residential terrace property. It is understood that the Client wishes to construct an extension to the existing lower ground floor of the property.

It is understood that the lower ground floor extension will be constructed using traditional spread foundations, reinforced concrete retaining walls and underpinning. The formation level of the extension is estimated to be at 3.00m bgl.

There is the potential for ground movements due to the proposed development from the wall installation and from the excavation process.

The magnitude and extent of ground movements resulting from installation of a secant/contiguous piled wall and excavation (in front of such a wall) are typically estimated based on the guidance given in the CIRIA publication C580 Embedded Retaining Walls – Guidance for Economic Design. The guidance in the CIRIA publication is based on the behaviour of embedded walls at numerous sites in London, which are predominantly walls embedded in London Clay, though typically with some near surface deposits consisting of River Terrace Deposits and Made Ground.

BUILDING DAMAGE ASSESSMENT

There is the potential for ground movements due to the proposed development from the wall installation and from the excavation process. It has been assumed that the excavation will be undertaken using the traditional method of underpinning up to a depth of approximately 3.0m.

It is envisaged that the excavation to be undertaken in the rear garden is relatively small compared to that at the front of the property. On this basis, a conservative approach has been adopted and the building damage assessment has focused on the underpinning works to be undertaken in the front garden to ensure the worst case is considered.

C580 provides curves estimating horizontal and vertical ground surface movements due to piled wall installation and to excavation in front of wall. Total ground movements resulting from the excavation will be the combination of the installation movements and the excavation movements.

Ground Movements Arising from Wall Installation

It has been assumed that the movements resulting from excavation in front of the underpins also incorporate the movements resulting from the construction (i.e. installation) of the underpins, since, unlike for the piles, the construction process requires an excavation prior to the pins being formed.

GROUND MOVEMENT

Ground Movements Arising from Excavation in front of Wall

The method provided within Box 2.5 in CIRIA C580 has been used to inform the assessment. However, consideration has also been given to recorded firm (and locally soft) nature of the soils over the excavation depth, as outlined in the following section.

The factor of safety against basal heave according to Terzaghi's method (1943) and the system stiffness have been preliminary assessed based on a Cu of 35kPa for soft to firm clay. A Factor of Safety (FoS) of about 7.5 and a system stiffness greater than 3000 have been estimated (see sheet 2, **Appendix A**). However, within the assessment a FoS of 3 has been applied in accordance with the approach by Clough et al (1989), see sheet 2, **Appendix A**).

Fig.2.13 in CIRIA C580 (from Clough 1989) indicates that the ratio between the maximum lateral wall movement and the excavation depth is in the order of 0.2% for such FoS and system stiffness values. According to Peck (1969) and Clough and Davidson (1977) the maximum inward movement of the wall may be in the order of 0.3% of the excavation depth in soft to firm clays.

Furthermore Moormann (2004) carried out extensive empirical studies of retaining wall and ground movements due to excavation in soft soil (cu<75kPa). He found that the ratio between the maximum vertical settlement at the ground surface behind a retaining wall and the maximum horizontal wall displacement varies between 0.5% and 1.0% (see sheet 2, **Appendix A**).

In the absence of underpinning specific guidance, Fig. 2.11a and Fig. 2.11b from CIRIA C580 have been used based on the above implications to reflect the soft to firm nature of the soil excavated.

As such, the ratio between the maximum lateral wall movement and the excavation depth and the ratio between the maximum ground settlement and the excavation depth have been conservatively taken as 0.3% at the wall location.

This is a conservative approach as the underpinned walls will be fully propped in both temporary and permanent cases and as such the ‘high stiffness’ assumption in C580 would be valid.

Using these predicted movements, estimates of possible damage have been made for the surrounding structures, based on the Damage Classification Scheme proposed by Burland and Wroth (1974).

Summary of Results

Copies of worksheets calculations and graphical representation of the results are presented in **Appendix A** and are summarised in the table below:

Nearby Building / Structure	Estimated Damage Category No.	Category of Damage	Comments
42 to 53 Mornington Terrace	n/a	n/a	Outside zone of influence of ground movement.

GROUND MOVEMENT

Nearby Building / Structure	Estimated Damage Category No.	Category of Damage	Comments
30 to 41 Mornington Street	n/a	n/a	Outside zone of influence of ground movement.
10 to 29 Albert Street	n/a		
Subject Property (47 Albert St)	2	Slight	Cracks easily filled. Redecoration probably required. Crack width <5mm.
49 Albert Street	1	Very Slight	Fine cracks that can easily be treated during normal decoration.
49 Albert Street – Party Wall	2	Slight	Cracks easily filled. Redecoration probably required. Crack width <5mm.
45 Albert Street	1	Very Slight	Fine cracks that can easily be treated during normal decoration.
45 Albert Street – Party Wall	2	Slight	Cracks easily filled. Redecoration probably required. Crack width <5mm.

The ground movement assessment undertaken indicates that damage to the subject property and surrounding properties will be between Burland Categories 1 (Very Slight) and 2 (Slight).

Anticipated vertical movements provide a maximum tilt of about 1 in 1500, which is well within generally tolerable differential movement (see **Appendix A**).

ADDITIONAL CONSIDERATIONS

Potential for Heave, Settlement & Inward Yielding

The removal of the overburden during the excavation of the basement is likely to result in some inward yielding of soils at formation level and possibly a subsequent settlement of the soils outside the excavation. In sandy soils the effects tend to be limited by their relatively low compressibility (as compared to soft clay soils). Inward yielding in firm to stiff clays is typically in the range of 5-40mm (Tomlinson, M.J. (1986).

The estimated depth of excavation is 4.0m below current ground level, assuming an unsaturated unit weight of 18-20kN/m^3, the estimated unload due to the excavation would be in the order of 60-80kN/m^2.

As the lower ground floor extension will be beneath the front garden area, there will be a difference in load at formation inside and outside that could result in differential settlement.

As outlined, groundwater was not encountered at the anticipated formation level of the basement. However, it would be prudent to adopt a conservative approach in relation to the basement design and account for groundwater at a depth of approximately 1m bgl.

GROUND MOVEMENT

Experience suggests that such heave movements tend largely to be restricted to within the site boundary when excavations are created with contiguous/secant piled retaining walls, so it is not anticipated that the changes in loading at basement level will have a significant impact on any surrounding structures. However, based on the information presented above it is recommended that the basement design takes into account the following:

- The potential for short term and longer term heave and inward yielding during construction and following construction.
- The potential for differential heave that will occur in the areas of the basement and areas where the basement doesn't extend (i.e. rear garden).
- The potential for groundwater to cause both lateral and uplift pressure.
- The potential for groundwater ingress into the basement following construction.

Ground Movement & Construction

The predicted building damage during construction is based on a conservative approach and it is recommended that the contractor gives consideration to the Association of Specialist Underpinning Contractors (ASUC) guidelines which should provide some mitigate and reduce the potential movements.

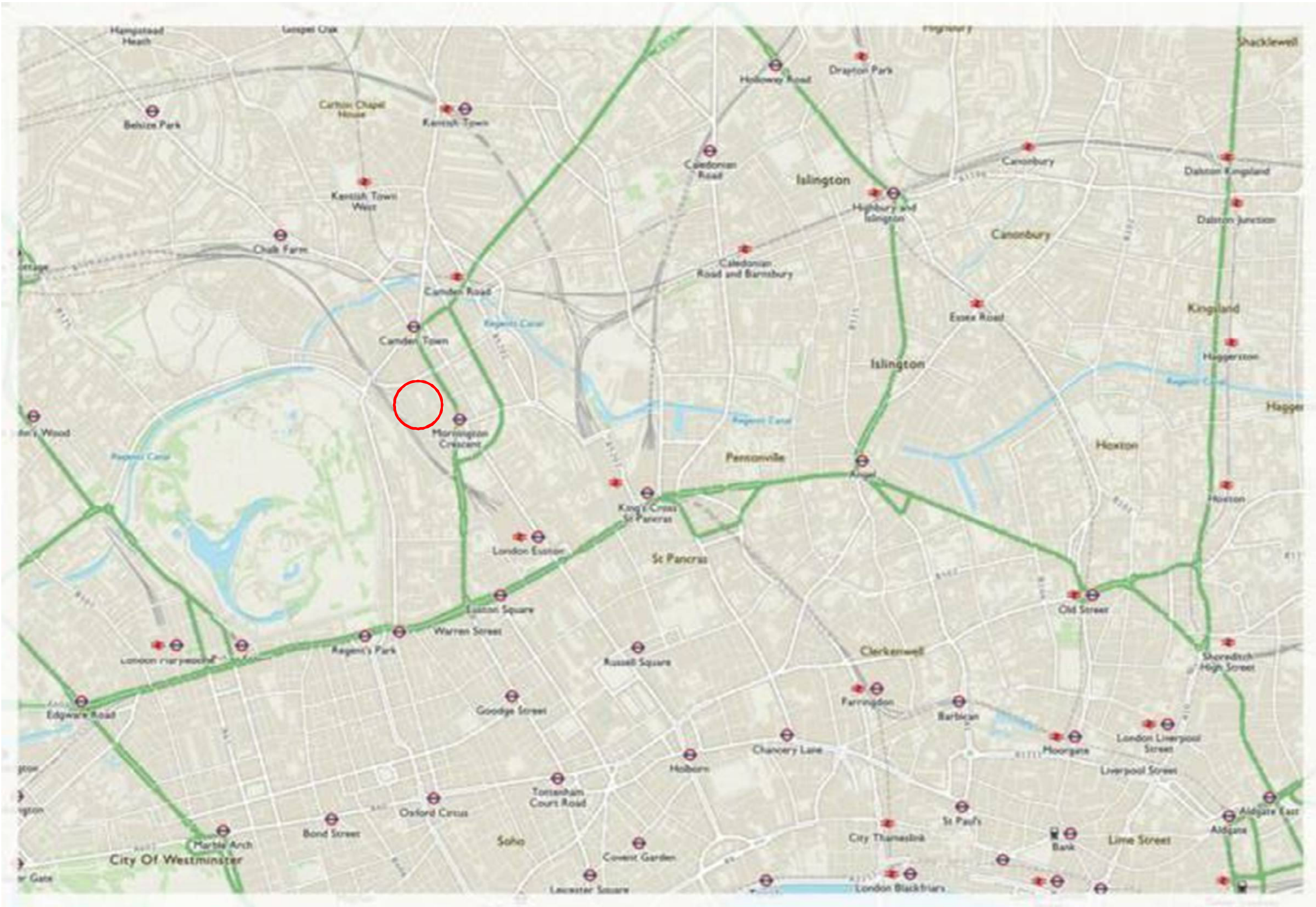
Ground Movements Monitoring

As a minimum, it is recommended that movement monitoring should be undertaken with surveying points set up using a total station prior to commencement of the works and it is recommended that monitoring be undertaken at weekly intervals. It is recommended that trigger values for monitoring are based on the predicted ground movements to ensure conservatism and that they are agreed under the Party Wall Act.

References

1. CIRIA C580 - Embedded Retaining walls: guidance for economic design, London 2003.
2. Moormann, C. Analysis of wall and ground movement due to deep excavation in soft soil based on a new worldwide database. Soils and Foundations, Vol. 44, No. 1, 87-98, 2004.
3. Peck, R.B. Deep excavations and tunnelling in soft ground. Proceedings of the 7th International Conference on Soil Mechanics. Mexico, State of the Art, pp. 225-290, 1969.
4. Clough, G.W. and Davidson, R.R. Effects of construction on geotechnical performance. Proceedings of the 9th International Conference on Soil Mechanics. Tokyo, Specialty Session, p. 3, 1977.
5. Clough, G.W. et al. Movement control of excavation support systems by iterative design procedure. ASCE Foundation Engineering: current principles and practices. Vol 1, pp. 869-884, 1989.

FIGURES



N

Key:

Approximate site location

IMPORTANT – Please Read

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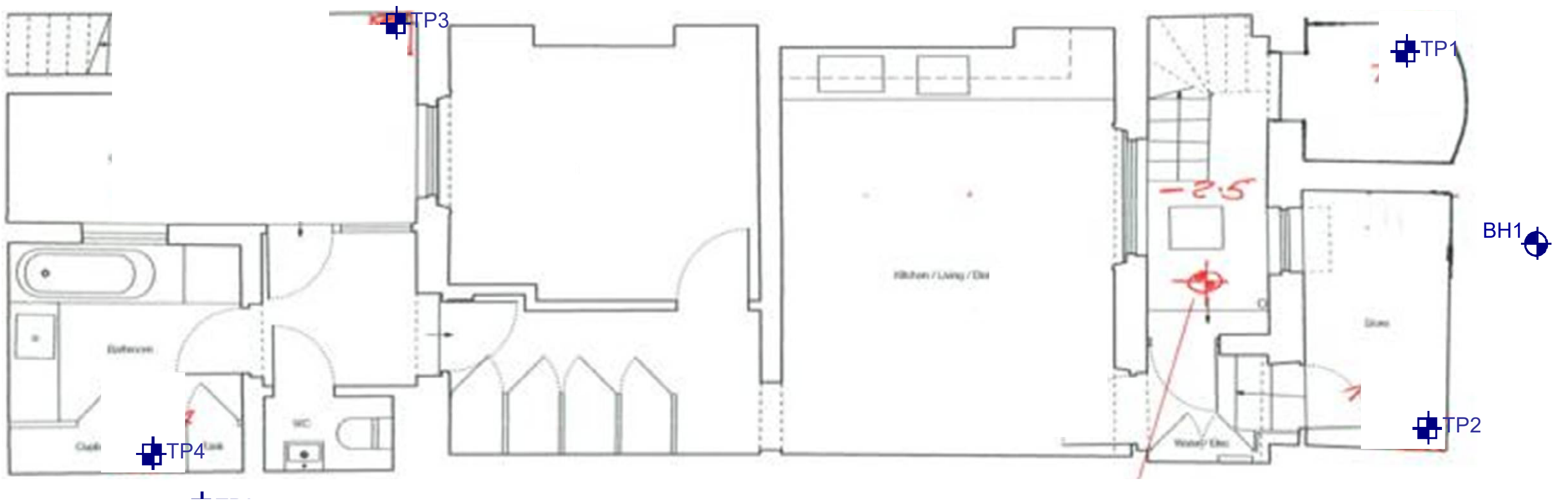
Site: 47 Albert Street, London NW1

Figure Number: Figure 1

Title: Site Location Plan

Project No:	Created By:	Date:
	PIL	August 2016

Client: Mr Neil & Mrs Angela Moran



Key:

BH Borehole location

TP Trial Pit location

IMPORTANT – Please Read

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Site:	47 Albert Street, London NW1
Figure Number:	Figure 2
Title:	Exploratory Hole Location Plan

Project No:	**Created By:**	**Date:**
	PIL	August 2016

Client: Mr Neil & Mrs Angela Moran

APPENDICES

Appendices

APPENDIX A GMA CALCULATION WORKSHEETS

Calc No.	Sheet No.	Rev
	1	A

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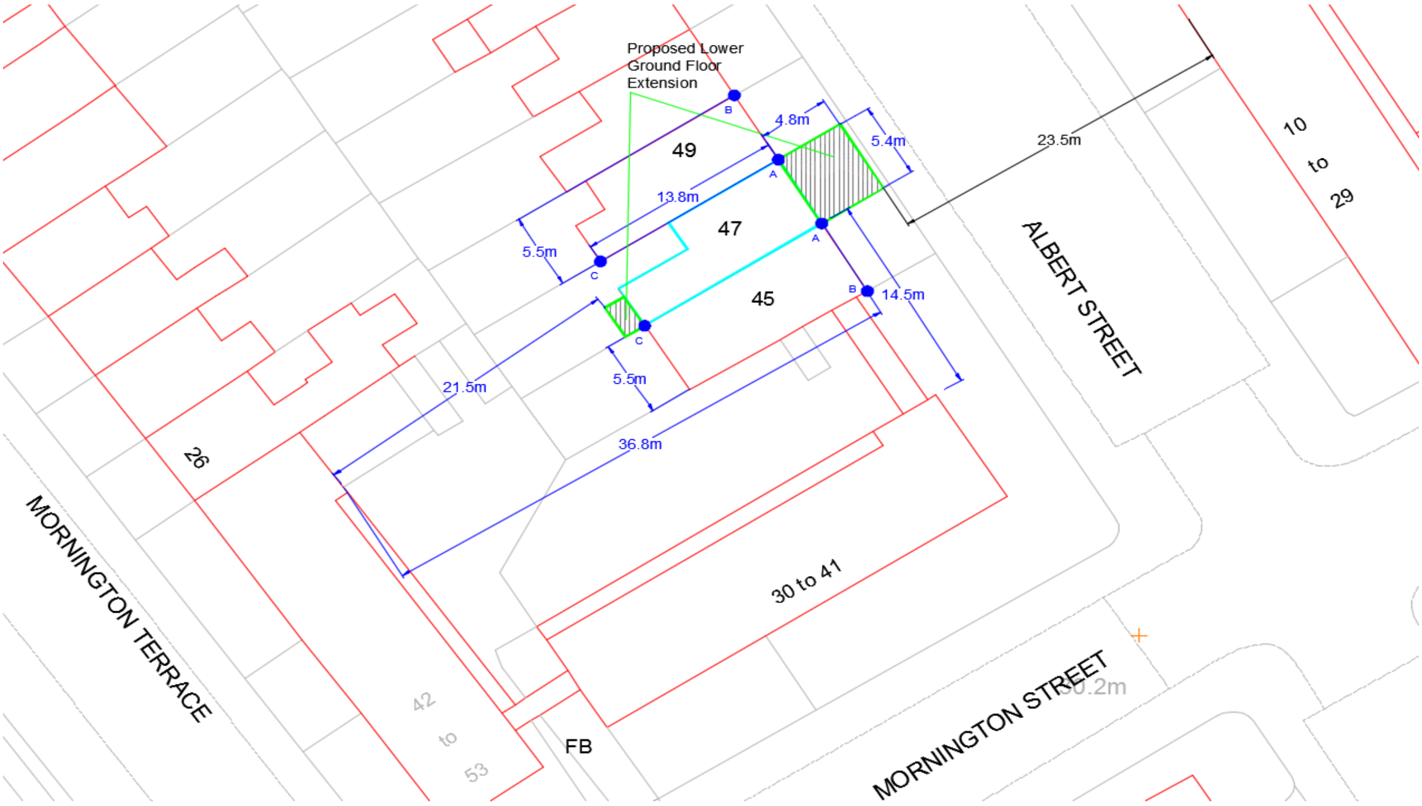
Calculation Sheet

Project	Ground Movement Assessment	Made by	CC
Location	47 Albert Street - London NW1	Date	18.01.17



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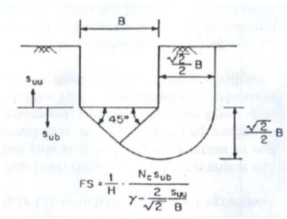
Calc No.	Sheet No.	Rev
	2	A

Calculation Sheet

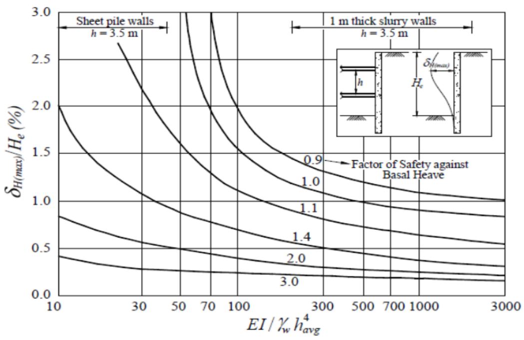
Project	Ground Movement Assessment	Made by	CC
Location	47 Albert Street - London NW1	Date	18.01.17



B	5.4 m		Excavation Width
H	3 m		Excavation Depth
Nc	5.7		
Cu	35 kPa		Undrained Shear Strenght
γ_s	18 kN/m³		Bulk Unit Weight of Soil
FoS	7.5		Factor of Safety against Bottom Heave (after Terzaghi, 1943)

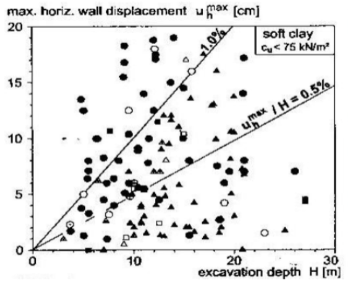
Ground movements arising from excavationin fornt of wall

Terzaghi's Method to assess Factor of Safety against Bottom Heave (1943).



E	3.00E+07 kPa		Wall Stiffness
b	0.4 m		Wall Width
I	0.00533 m^4/m		Moment of Inertia
γ_w	10 kN/m³		Bulk Unit Weigth of Water
h	1.5 m		Props Vertical Spacing
ρ_s	3160		System Stiffness (after Clough et al, 1989)

Lateral wall movements as a percentage of excavation deph versus system stiffness (Clough et al. 1989).



Variation of maximum horizontal displacement with excavation depth following Moormann (2004).

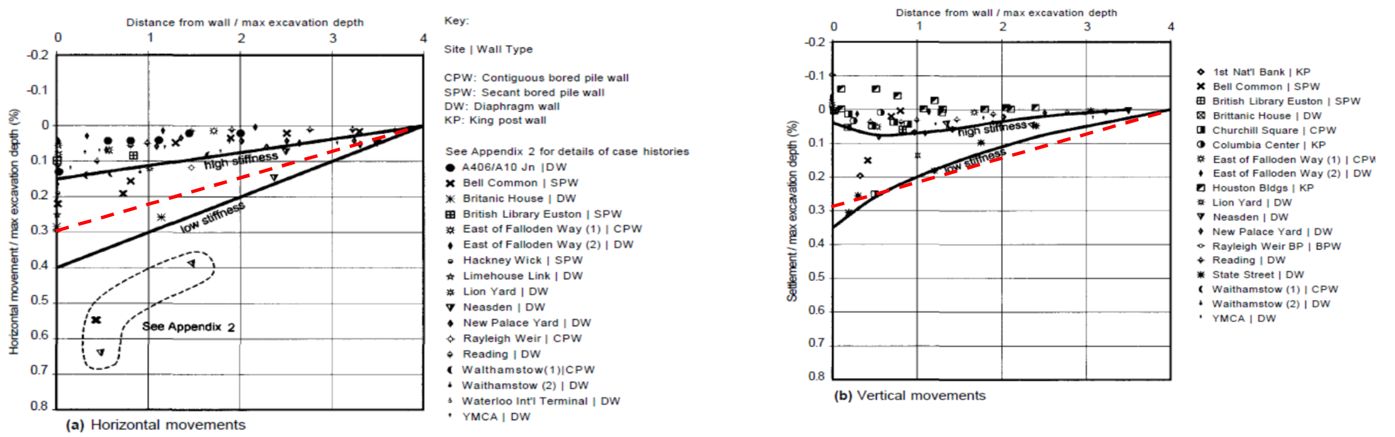


Figure 2.11 *Ground surface movements due to excavation in front of wall in stiff clay*

Calc No.	Sheet No.	Rev
	3	A

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Calculation Sheet

Project	Ground Movement Assessment	Made by	CC
Location	47 Albert Street - London NW1	Date	18.01.17

Assumptions
Excavation depth - 3.0m
Underpinning to -3.0m
Propping System will be utilised

Max Excavation Depth 3.0 m
Wall Depth 3.0 m

Nearby Structure	Note	Point	Distance from wall (m)	Ground movements arising from excavation in front of wall				
				Distance from wall / max excavation depth	Horizontal movement / max excavation depth (%) Fig. 2.11a	Horizontal movement (mm)	Settlement / max excavation depth (%) Fig. 2.11b	Vertical movement (mm)
49 Albert Street		A	0.0	0.0	0.3	9.0	0.3	9.0
		B	5.5	1.8	0.17	5.1	0.13	3.9
49 Albert Street	Party Wall	A	0.0	0.0	0.30	9.0	0.3	9.0
		C	13.8	4.6	0	0.0	0	0.0
45 Albert Street		A	0.0	0.0	0.30	9.0	0.3	9.0
		B	5.5	1.8	0.17	5.1	0.13	3.9
45 Albert Street	Party Wall	A	0.0	0.0	0.3	9.0	0.3	9.0
		C	13.8	4.6	0	0.0	0	0.0

Nearby Structure	Total Movements											
	Corner Effect	Horizontal movement (mm)	Vertical movement (mm)	L (m)	H (m)	L/H	Δ (mm)	Tilt (1/x)	M=Δ/L (%)	δh (mm)	εh=δh/L (%)
49 Albert Street	Y	4.5	4.5	5.5	10.0	0.6	2.6	2157	0.046	2.0	0.035
		2.6	2.0								
49 Albert Street - Party Wall	N	9.0	9.0	13.8	10.0	1.4	9.0	1533	0.065	9.0	0.065
		0.0	0.0								
45 Albert Street	Y	4.5	4.5	5.5	10.0	0.6	2.6	2157	0.046	2.0	0.035
		2.6	2.0								
45 Albert Street - Party Wall	N	9.0	9.0	13.8	10.0	1.4	9.0	1533	0.065	9.0	0.065
		0.0	0.0								

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Calc No.	Sheet No.	Rev
	4	A

Calculation Sheet

Project	Ground Movement Assessment	Made by	CC
Location	47 Albert Street - London NW1	Date	18.01.17