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Our Ref: 15189 March 2016

28 HARLEY ROAD, LONDON NW3

RESPONSE TO QUERIES RAISED IN CAMPBELL REITH'S BASEMENT IMPACT ASSESSMENT AUDIT

INTRODUCTION:

Michael Chester & Partners prepared a structural Basement Impact Assessment (BIA) to accompany a planning application by Construct 360. The application included numerous structural alterations to the super structure of the building plus proposals for a single storey basement across most of the footprint of the existing building.

Campbell Reith act on behalf of London Borough of Camden and have prepared an Audit Report of the BIA. The following addresses the queries raised by Campbell Reith in the Audit Tracker contained within Appendix 2 of their report. The queries are reproduced for ease of reference.

QUERIES RAISED IN AUDIT TRACKER REPORT:

1. Some proof of experience in ground engineering for the author of land stability section of the BIA is required.

The author of the report, Duncan Mercer, has been a chartered member of the Institution of Structural Engineers since 1994 and has worked on many successful basement projects in and around London over the course of the years, including –

53A Elsworthy Road, NW3:	large single storey basement, full footprint of building, combined with substantial alterations and re-modelling of the superstructure.
No.1 Pilgrim's Lane NW3	large single storey basement, full footprint of building, combined with substantial alterations and re-modelling of the superstructure.
Wildwood Road, NW11	large single storey basement on a piled foundation, full footprint of building with minor structural alterations to superstructure.
No.4 Oldbury Place, W1	single storey basement over 2/3 footprint of building with minor alterations to the superstructure.

2. Site Investigation report has to be submitted, including; site walkover study, clarification on the groundwater level with subsequent monitoring, geotechnical model and recommendations on basement/ retaining wall design parameters.

Trial pits were excavated around the property as part of the original BIA to establish the existing foundation regime and underlying ground conditions. The trial pit locations were agreed following a detailed walkover study, site inspection and assessment of the existing superstructure by the author The results were included in the original BIA and confirmed that the house was founded in firm clay and that it had been previously underpinned. Water was found in one trial pit at the front left of the house. It was not considered to be ground water but was thought to be coming from a leaking pipe. This was because the pit was located directly adjacent to both the water meter and the ground floor WC and no water was found in the other trial pits.

Three additional trial pits have now been excavated to 3m depth (locations indicated on appended Architect's drawing number HR28/1001revA) and the results are appended herewith as Appendix A. The additional trial pits found gravelly clayey Made Ground typically to about 0.5m depth (to 2.7m depth in trial pit 1 adjacent to an underpinned foundation) overlying firm, becoming stiff, greyish brown mottled orange and brown clay (London Clay). No water was recorded in these trial pits.

In terms of a geotechnical model, the site is generally level and is overlain by Made Ground to approximately 0.5m deep over London Clay. British Geological Society boreholes to the north, south, east and west of the site prove the London Clay to depths variously between 20m and 30m. London Clay is considered to be in excess of 60m thick in this area of London. No significant water strikes are noted in the borehole logs that I have seen. Deeper areas of Made Ground have been found around the foundations and are consistent with backfilling the working spaces following underpinning. Some locally perched ground water may exist around the existing footings or in the topsoils and/or Made Ground but the presence of water is not generally considered to be a significant issue.

3. The BIA should be updated with address to the Source Protection Zone. See section 4.6.

See Hydrological response by JH Groundwater Ltd.

4. Building damage assessment is rejected on the basis that these are not correct. Calculations to be resubmitted to demonstrate that damage will be less than Category 1, otherwise mitigation measures have to be considered.

Amended drawings have been received from the Architect, copies attached, and these show that the light well has now been omitted from along the left-hand flank wall. At the closest point, the neighbour's building (No.30) is approximately 2.8m from the face of the No.28 Harley Road. The ages of the two buildings are similar so it is reasonable to assume that the foundations (ignoring the underpinning to No.28) are similar. The original foundations to No.28 are 550mm deep below ground level. Excavations for the basement will be approximately 3.4m deep below ground level so approximately 50mm below the 45 degree line of spread from the underside of No.30's footing.

The retaining wall is to be designed for at rest earth pressures (see point 5) with a maximum span to depth ratio of 7 modified as permitted by increasing the percentage of reinforcement. The retaining walls are to be cast in sections not exceeding 1m long in a carefully controlled hit-and-miss sequence. Concrete is to be cast directly against the exposed earth face thus eliminating the risk of voids being left behind the wall. Consequently it is considered that there is no significant risk of long term movement of the ground behind the wall and, therefore, no significant risk of movement in the building beyond.

5. Outline design for floor slab and retaining walls.

Calculations appended and provide designs for maximum dead plus live load and for minimum dead load. At rest pressures have been assumed along with a possible hydrostatic head of three quarters of the height of the wall.

6. The permanent exclusion of the groundwater from the proposed basement should be considered.

Agreed. The reinforced concrete is to be detailed to limit shrinkage cracking and hydrophilic water bars are to be provided at all construction joints. A drained cavity membrane system is to be provided as a secondary means of protection.

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APPENDIX A

28 HARLEY ROAD, LONDON NW3

ADDITIONAL SITE INVESTIGATION INFORMATION

Trial Pit/Trench Description **TP01**

OJ Environmental Consultancy

Land Quality Assessors and Contaminated Land Specialists

Depth (m)	Description of strata	Sample	Type	Water	Remarks
0.00-0.10	Concrete Slab	N/A	N/A	Dry	Made Ground. Grass and roots.
0.10-2.60	MADE GROUND comprised of existing concrete columns with occasional cross mesh rebar	N/A	N/A	Dry	Made Ground. Organic fragments estimated at <1%.
2.60-2.70	Firm to stiff brown gravelly sandy CLAY with low subangular concrete cobble. Gravel is angular to subangular concrete and brick (MADE GROUND)	N/A	N/A	Dry	Made Ground. Organic fragments estimated at <1%.
2.60-3.00	Firm becoming stiff with depth greyish brown mottled orange and brown CLAY with rare fine and medium gravel sized roots and rootlets. (LONDON CLAY).	N/A	N/A	Dry	London Clay with Organic fragments estimated at <1%.

Trial Pit Length (m): 8.00 X 7.50 X 3.00

Groundwater Observation: Dry

Shoring: None

Weather: Rain

Comments: Depths are given from lowest point of surface at trial pit location: the base of the landscaped bund at this location. Pits excavated with JCB 3CX tracked excavator with 3ft bucket.

Project	Trial Pit No	Logger	Date	Job No:
28 Harley Road, London	TP01	OJ	05/03/2016	D28H

Trial Pit/Trench Description **TP02**

OJ Environmental Consultancy

Land Quality Assessors and Contaminated Land Specialists

Depth (m)	Description of strata	Sample	Type	Water	Remarks
0.00-0.10	Concrete Slab	N/A	N/A	Dry	Made Ground. Grass and roots.
0.10-0.40	Dark brown slightly gravelly sandy clayey SILT with low subangular brick cobble content. Gravel is angular and subangular fine to coarse flint, concrete and brick. Rare fine ash. (MADE GROUND).	N/A	N/A	Dry	Made Ground. Organic fragments estimated at <1%.
0.40-3.00	Firm becoming stiff with depth greyish brown mottled orange and brown CLAY with rare fine and medium gravel sized roots and rootlets. (LONDON CLAY).	N/A	N/A	Dry	London Clay with Organic fragments estimated at <1%.

Trial Pit Length (m): 2.00 X 1.50 X 3.00

Groundwater Observation: Dry

Shoring: None

Weather: Rain

Comments: Depths are given from lowest point of surface at trial pit location: the base of the landscaped bund at this location. Pits excavated with JCB 3CX tracked excavator with 3ft bucket.

Project	Trial Pit No	Logger	Date	Job No:
28 Harley Road, London	TP02	OJ	05/03/2016	D28H

Trial Pit/Trench Description **TP03**

OJ Environmental Consultancy

Land Quality Assessors and Contaminated Land Specialists

Depth (m)	Description of strata	Sample	Type	Water	Remarks
0.00-0.10	Concrete Slab	N/A	N/A	Dry	Made Ground. Grass and roots.
0.10-0.50	Dark brown slightly gravelly sandy clayey SILT with low subangular brick cobble content. Gravel is angular and subangular fine to coarse flint, concrete and brick. Rare fine ash. (MADE GROUND).	N/A	N/A	Dry	Made Ground. Organic fragments estimated at <1%.
0.50-3.00	Firm becoming stiff with depth greyish brown mottled orange and brown CLAY with rare fine and medium gravel sized roots and rootlets. (LONDON CLAY).	N/A	N/A	Dry	London Clay with Organic fragments estimated at <1%.

Trial Pit Length (m): 2.00 X 1.50 X 3.00

Groundwater Observation: Dry

Shoring: None

Weather: Rain

Comments: Depths are given from lowest point of surface at trial pit location: the base of the landscaped bund at this location. Pits excavated with JCB 3CX tracked excavator with 3ft bucket.

Project	Trial Pit No	Logger	Date	Job No:
28 Harley Road, London	TP03	OJ	05/03/2016	D28H

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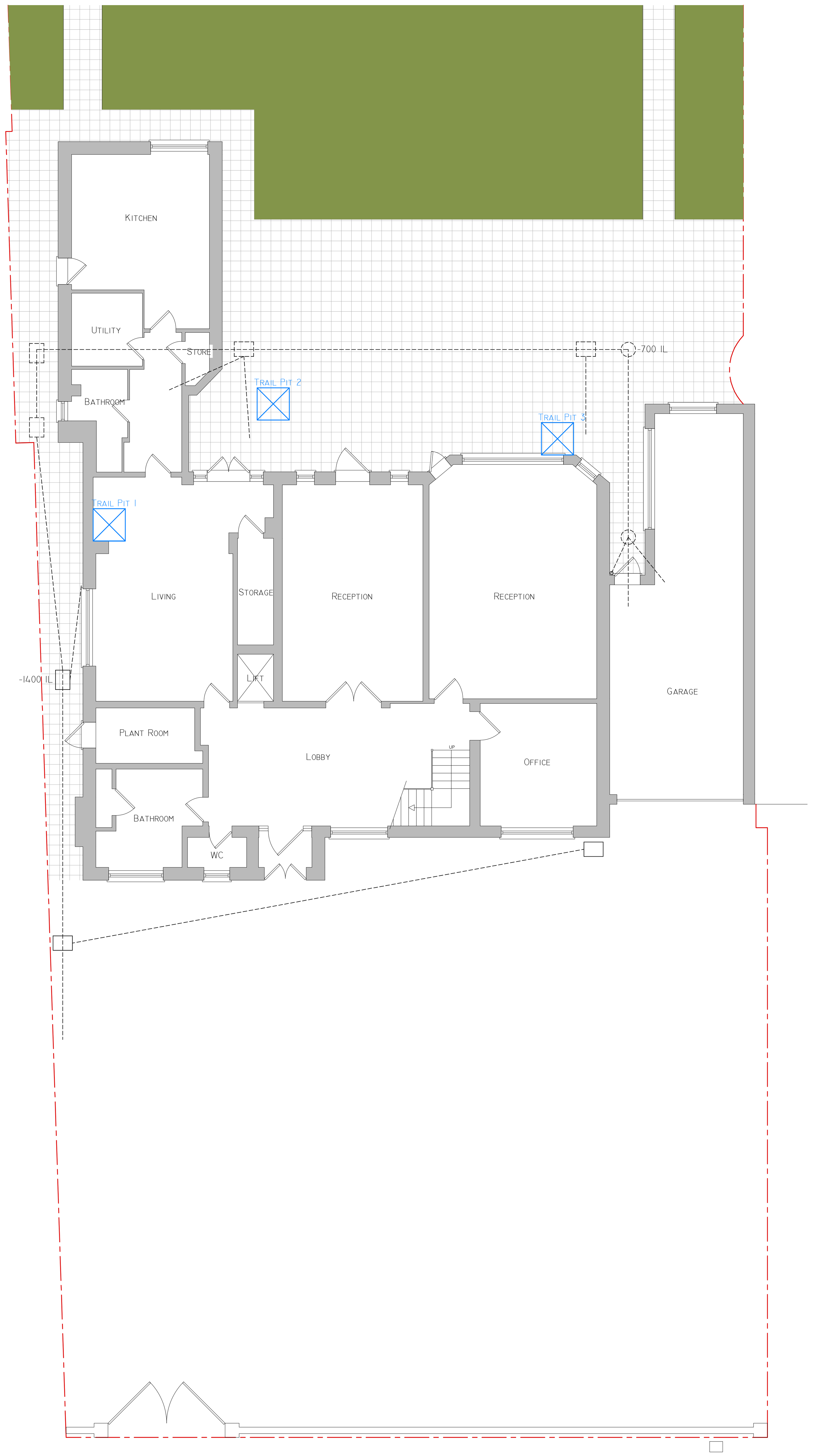
APPENDIX B

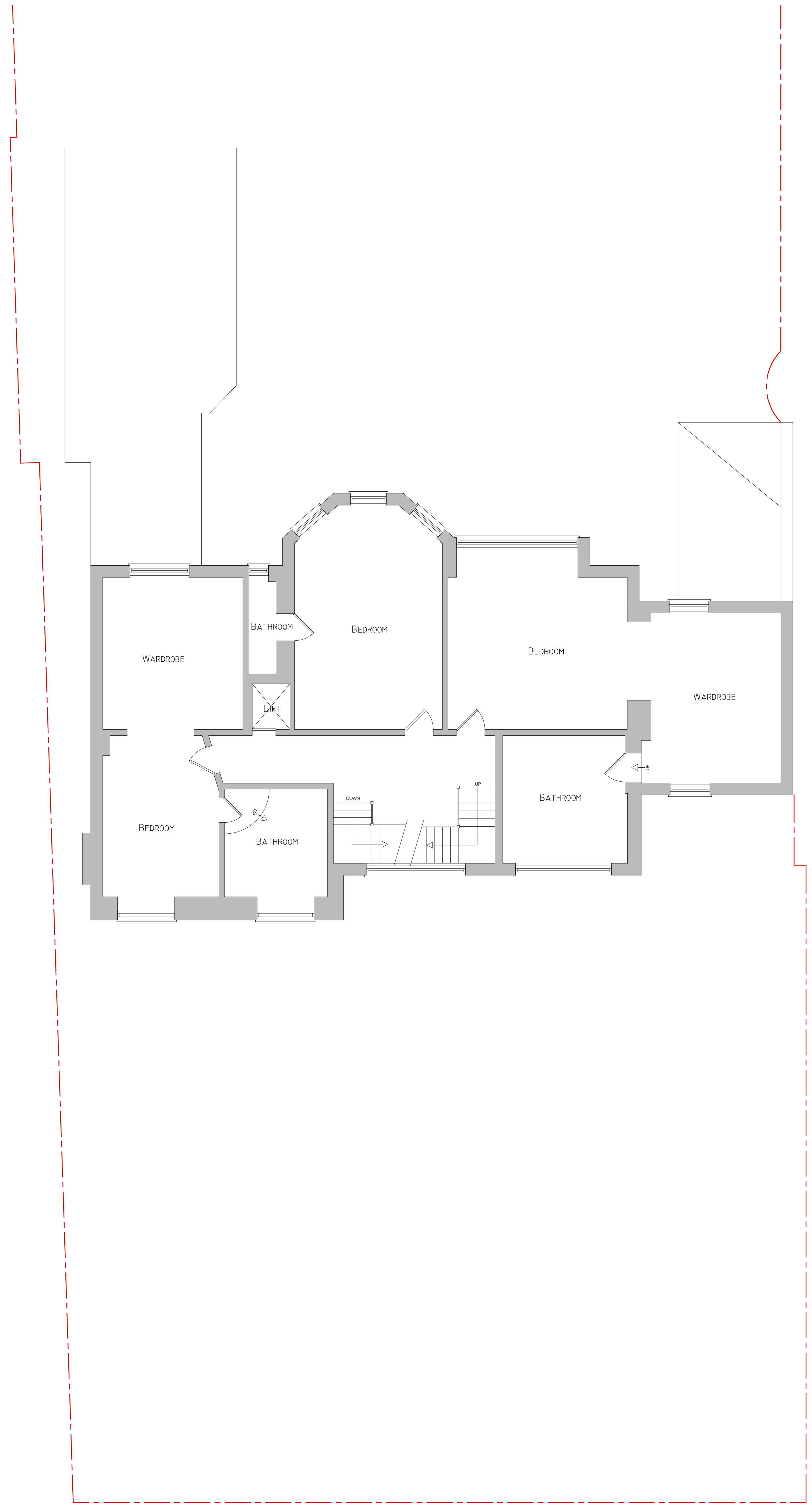
28 HARLEY ROAD, LONDON NW3

AMENDED ARCHITECTURAL DRAWINGS

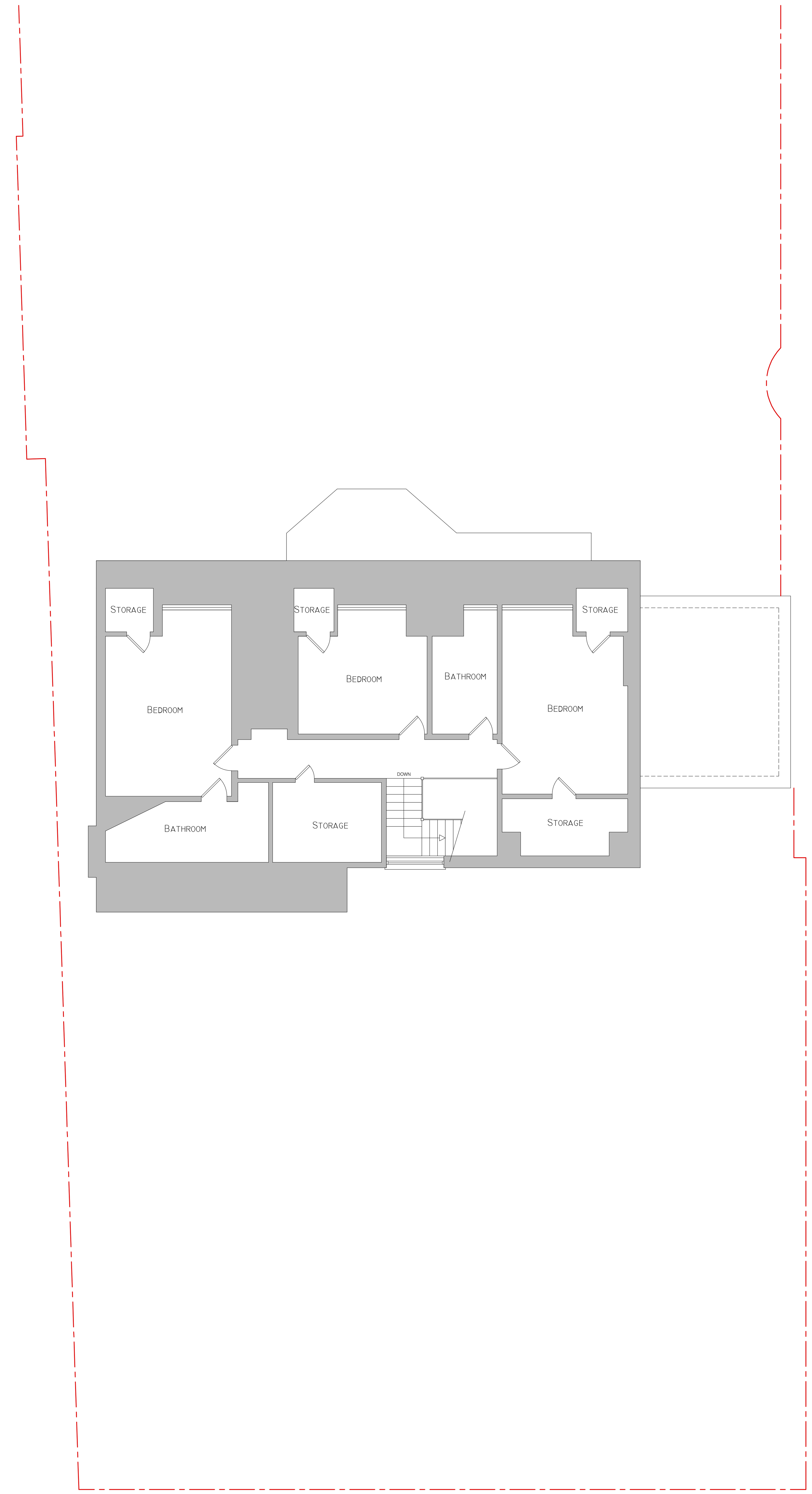
Please note that construction must only commence once planning, building control and any other approvals have been received. It is the responsibiltity of the owner/contractor to commence prior to these approvals.



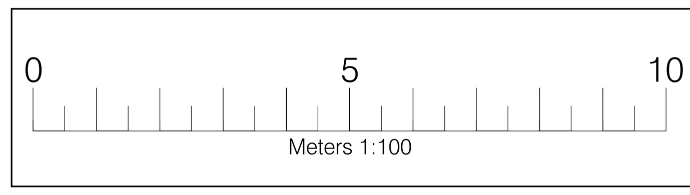
EXISTING GROUND FLOOR PLAN
SCALE 1:100



EXISTING FIRST FLOOR PLAN
SCALE 1:100



EXISTING LOFT FLOOR PLAN
SCALE 1:100



Legend	
Walls Removed	
New Walls	
Existing Walls to Remian	
Roof Structure	
Sound Seperating Walls	
Boundary	

IMPORTANT GENERAL NOTE
The specification is to be read in conjunction with the plans/section details, and other associated Structural details as may be provided.
All work is to be carried out to the Local Authority Planning and Building Regulations Approval, and the Codes of Practice and British Standards as necessary.
All dimensions, levels, sizes, positions and locations of particulars as indicated on drawings are to be verified by the appointed Contractor on site prior to engaging in works. Any discrepancies must be reported to the Architect/Surveyor/Engineer or responsible person/s immediately.
The Contractor is responsible for ensuring compliance with the CDM Regulations, and appropriate Health & Safety on site precautions.
The Client/Building Owner must obtain any necessary PARTY WALL AGREEMENTS, prior to engaging in the works on site.

Revision	Date	Description
A	18.01.16	Drains Added

Paper Size	A1
Scale	1:100
Revision	A
	Oct-15
Drawn By/Checked By	AP/HW

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Tel: 0208 206 0011

Site Address
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London
NW3 3BN

Existing
Plans

Drawing Number
HR28-1001

Please note that construction must only commence once planning, building control and any other approvals have been received. It is the responsibiltity of the owner/contractor to commence prior to these approvals.

EXISTING FRONT ELEVATION
SCALE 1:100

EXISTING SIDE ELEVATION
SCALE 1:100

EXISTING REAR ELEVATION
SCALE 1:100

EXISTING SIDE ELEVATION
SCALE 1:100

0 5 10
Meters 1:100

Legend	
Walls Removed	
New Walls	
Existing Walls to Remian	
Roof Structure	
Sound Seperating Walls	
Boundary	

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Revision	Date	Description

Paper Size: A1
Scale: 1:100
Revision: 1st
Oct-15
Drawn By/Checked By: AP/HW

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Existing Elevations

Drawing Number: HR28-1002

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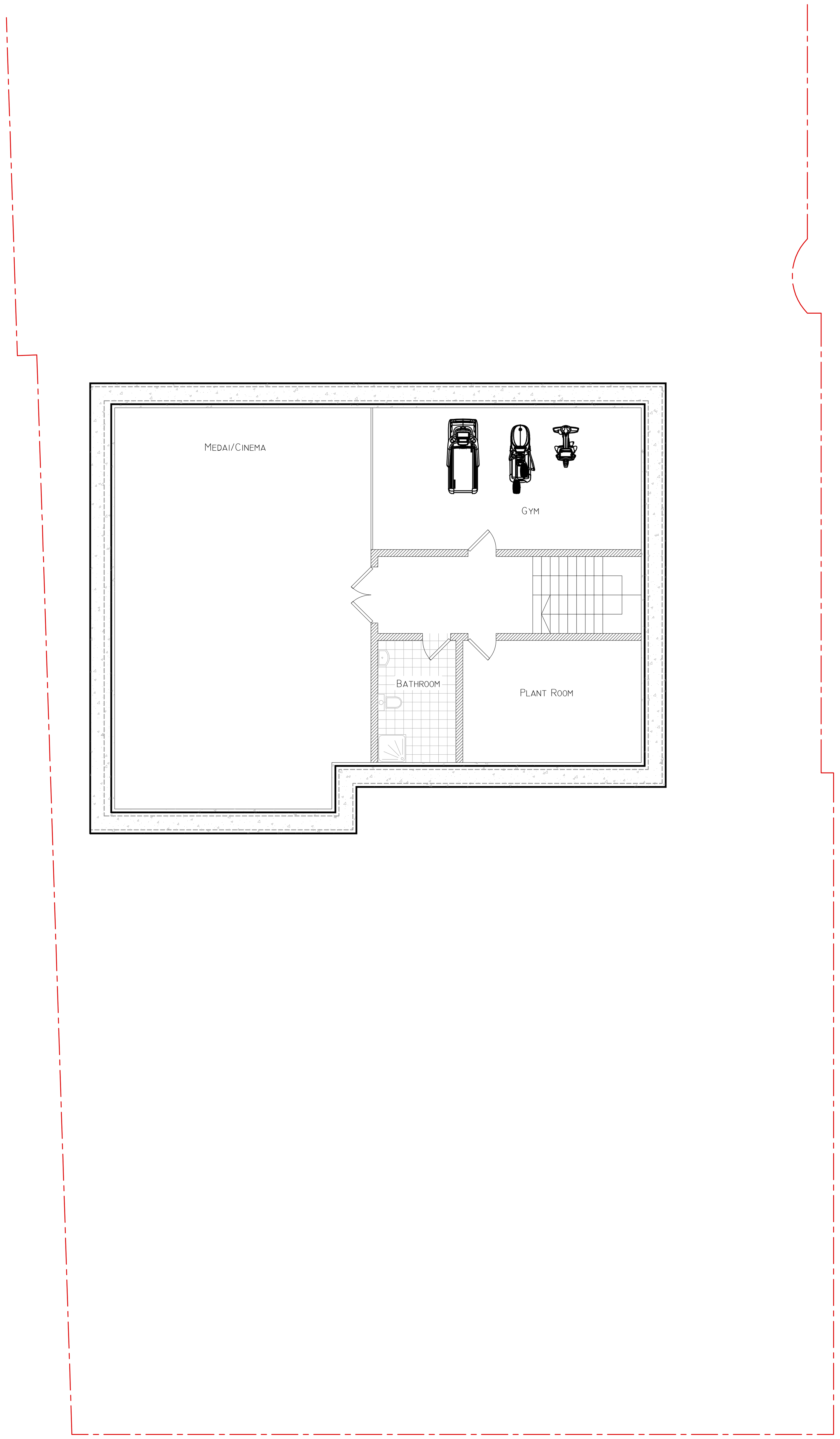
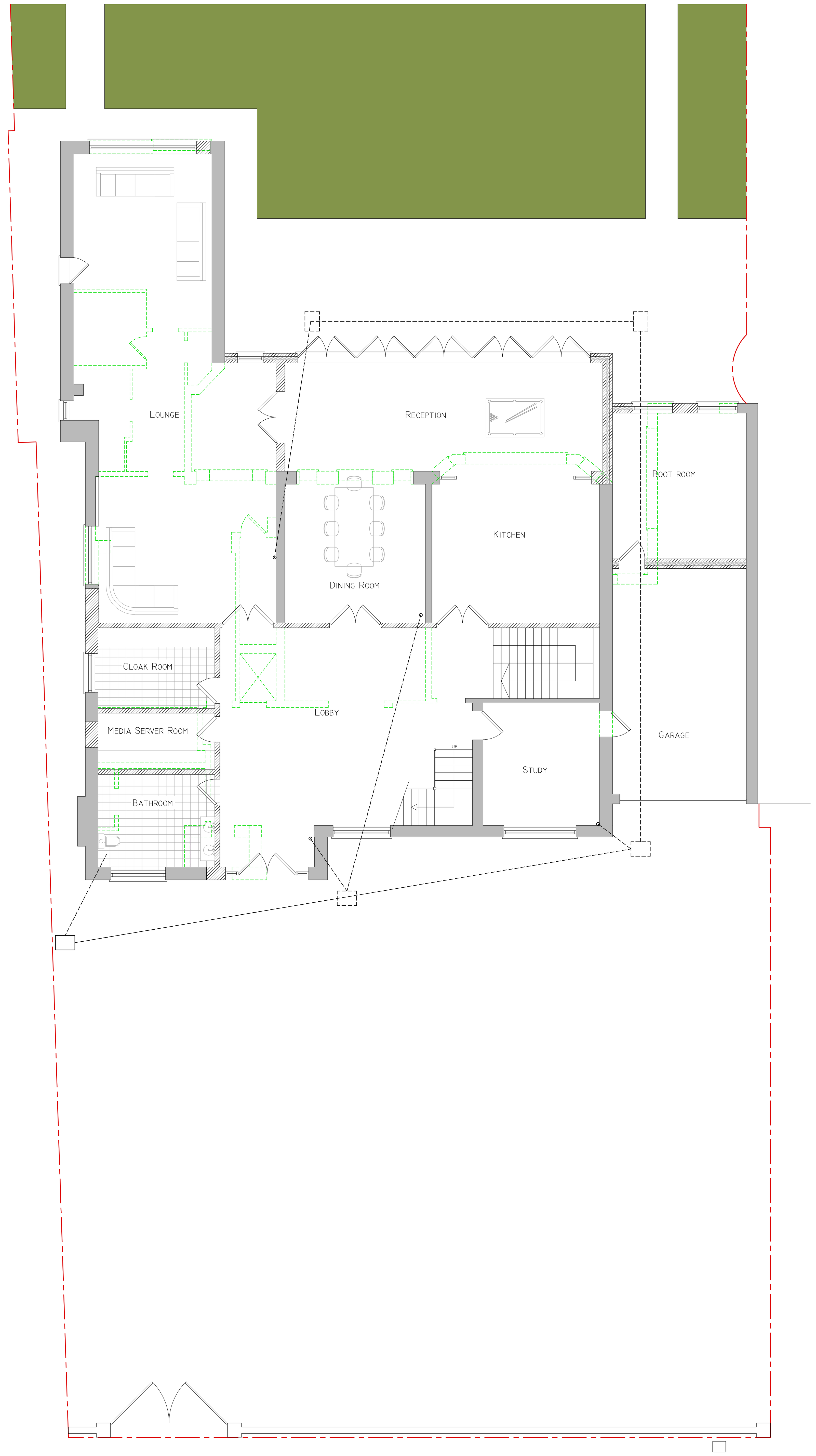
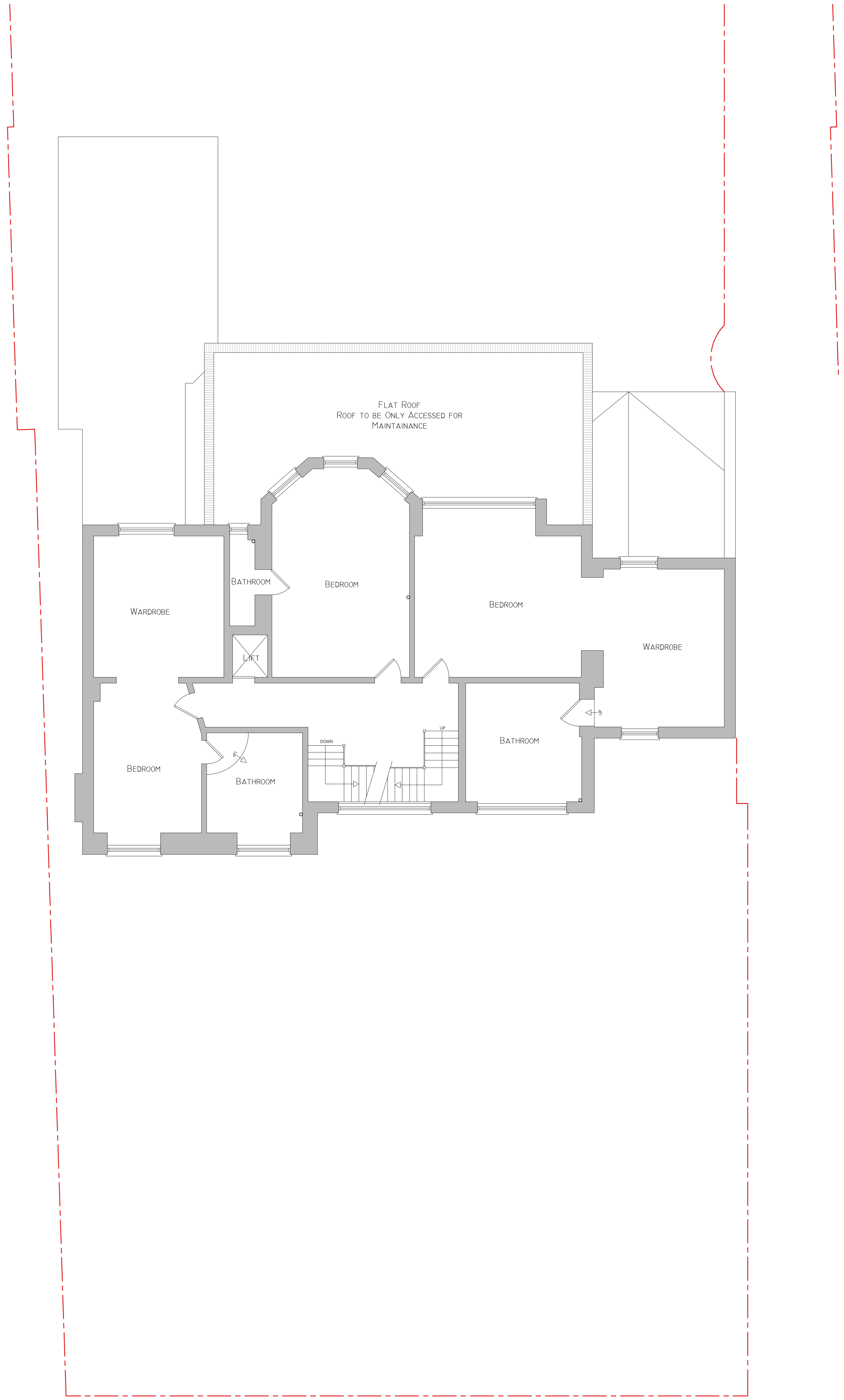


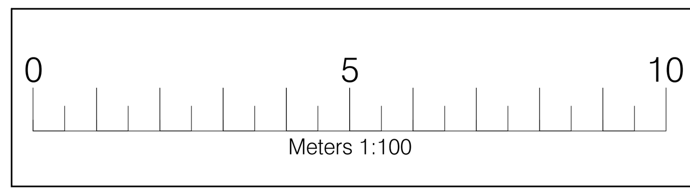
Proposed Basement Floor Plan
Scale 1:100



Proposed Ground Floor Plan
Scale 1:100



Proposed First Floor Plan
Scale 1:100



Legend
Walls Removed
New Walls
Existing Walls to Remian
Roof Structure
Sound Seperating Walls
Boundary

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Revision	Date	Description
A	18.01.16	Drains Added
B	01.02.16	Lightwell Removed
C	01.03.16	Roof Terrace Removed

Paper Size	A1
Scale	1:100
Revision	B
Date	Oct-15
Drawn By/Checked By	AP/HW
Site Address	28 Harley Road London NW3 3BN
Title	Proposed Plans
Drawing Number	HR28-1003C

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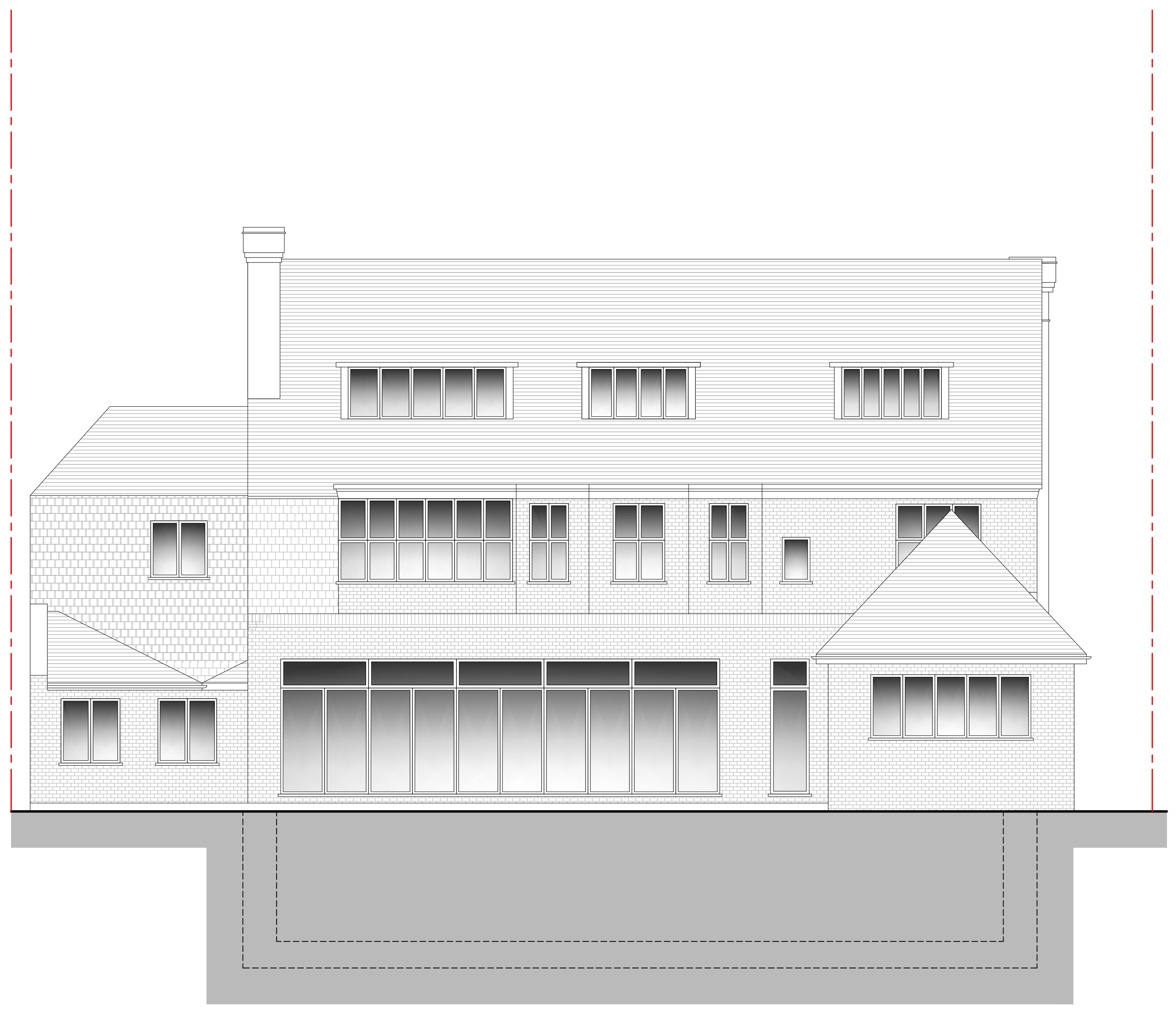
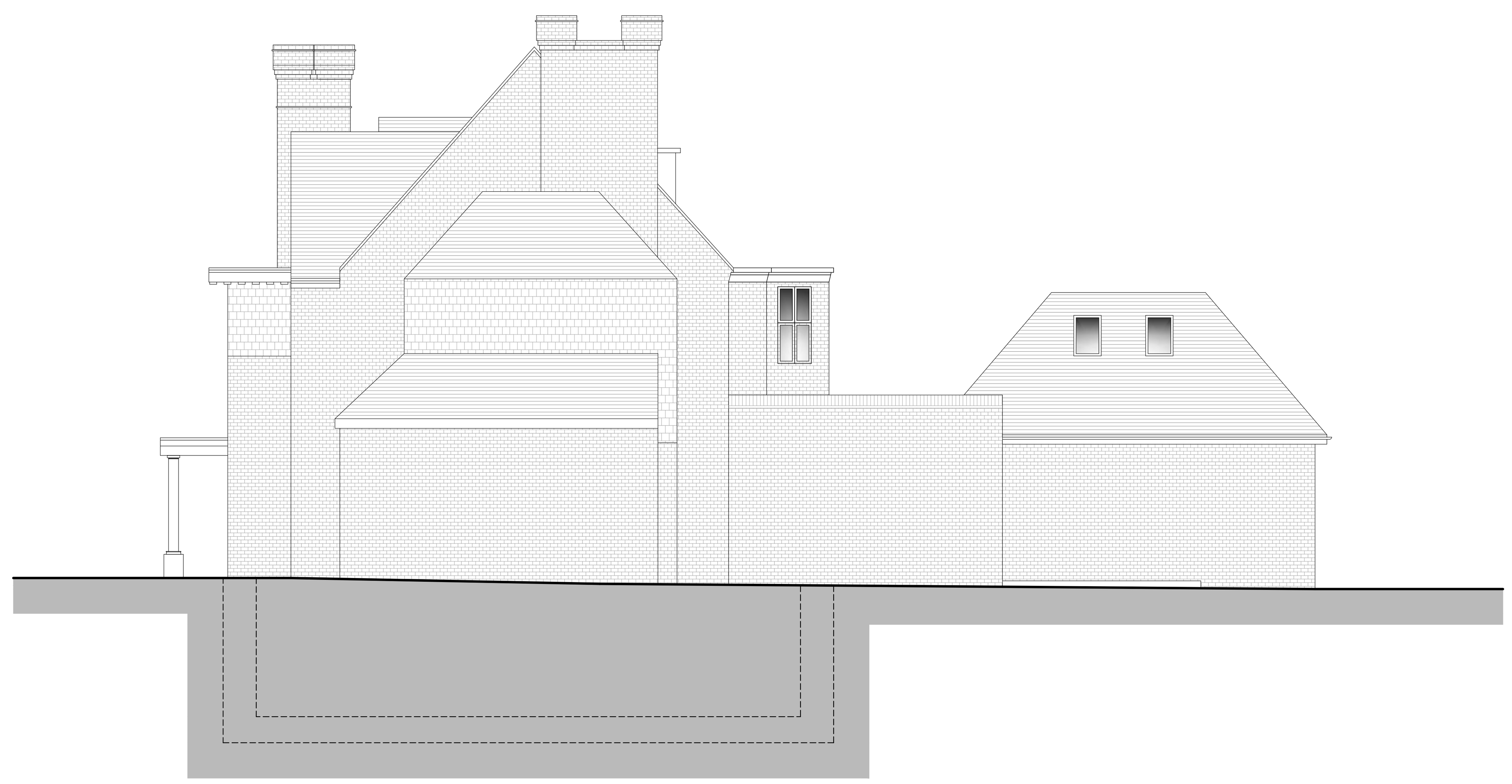
PROPOSED FRONT ELEVATION
SCALE 1:100

PROPOSED SIDE ELEVATION
SCALE 1:100



PROPOSED REAR ELEVATION
SCALE 1:100



PROPOSED SIDE ELEVATION
SCALE 1:100

0 5 10
Meters 1:100

Legend	
Walls Removed	
New Walls	
Existing Walls to Remian	
Roof Structure	
Sound Seperating Walls	
Boundary	

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Revision	Date	Description
A	01.02.16	Lightwell Removed
B	01.03.16	Roof Terrace Removed

Paper Size: A1
Scale: 1:100
Revision: B
Oct-15
Drawn By/Checked By: AP/HW

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Site Address
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London
NW3 3BN

Proposed Elevations

Drawing Number
HR28-1004B

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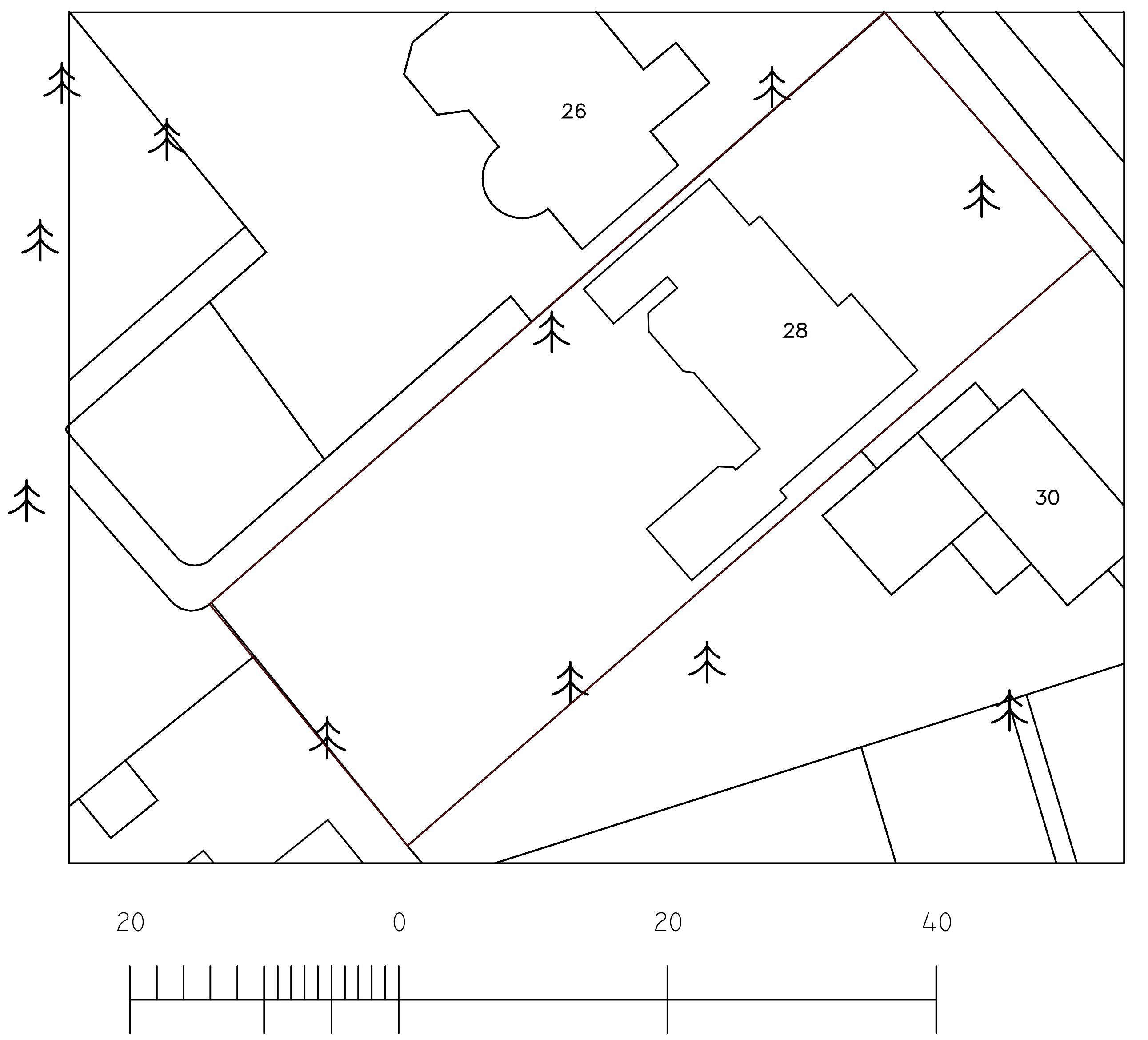
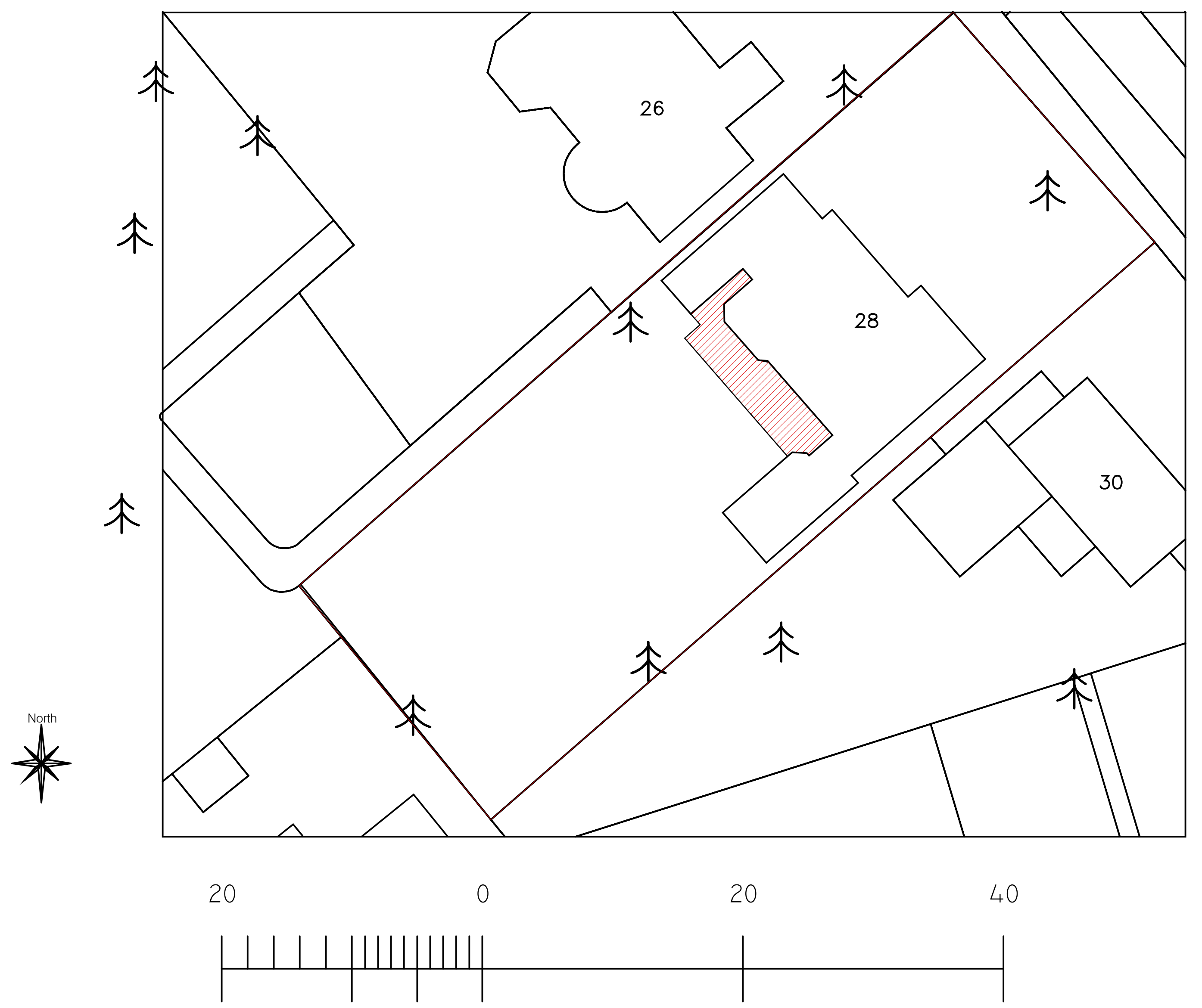
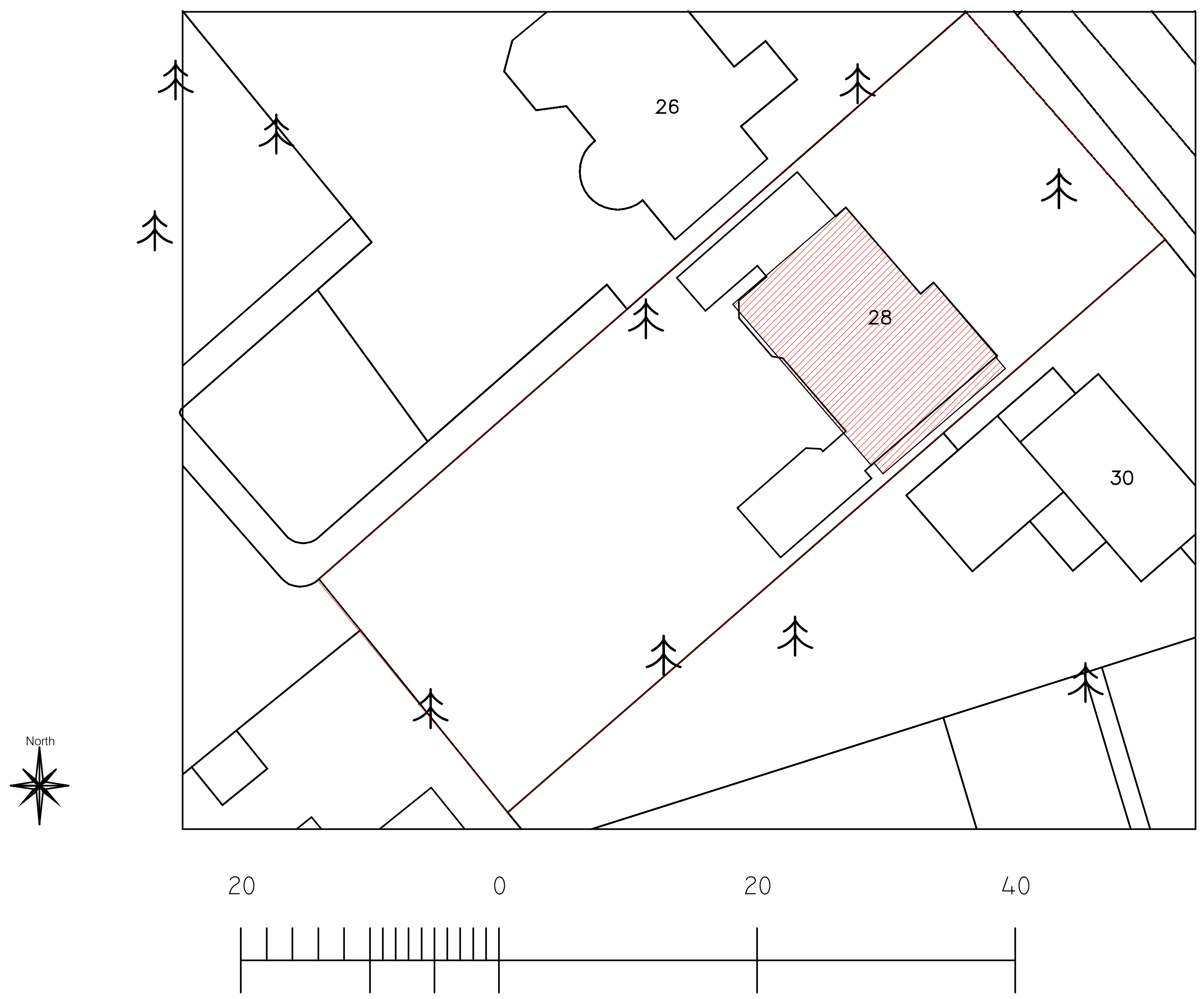


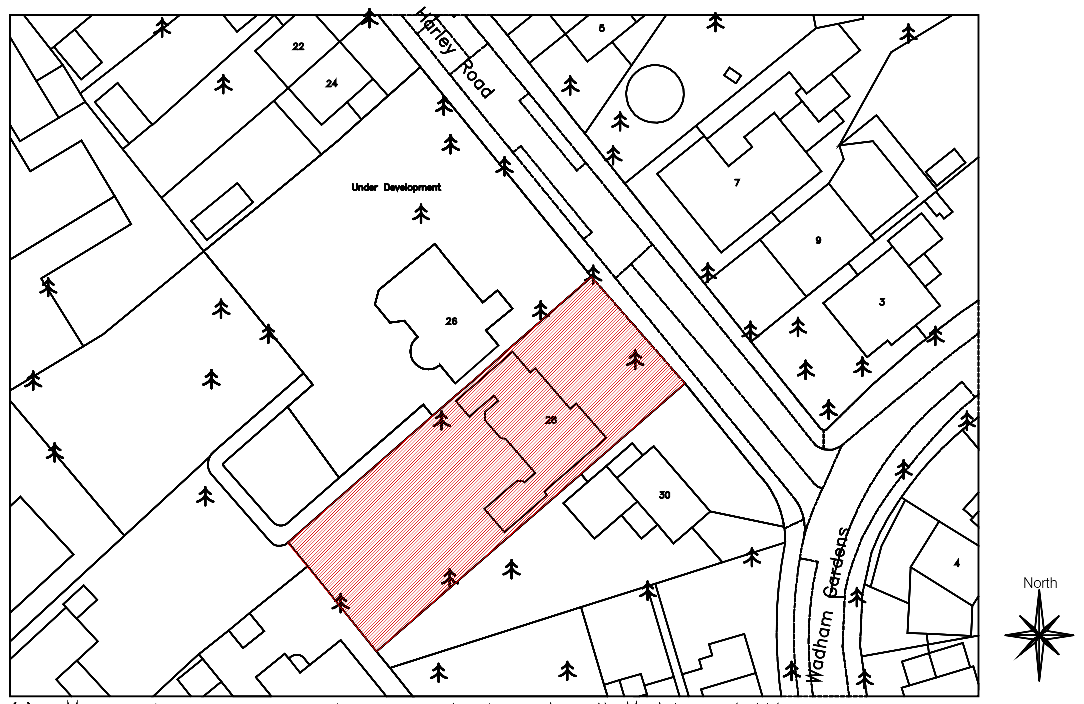
Existing Block Plan Scale 1:1250



Proposed Block Plan Scale 1:1250
Showing Extensions at Ground Floor Level



Proposed Block Plan Scale 1:1250
Showing Extensions at Basement Level



20 0 20 40 60 80 100

Location Plan Scale 1:1250

0 5 10

Meters 1:100

Legend	
Walls Removed	
New Walls	
Existing Walls to Remian	
Roof Structure	
Sound Seperating Walls	
Boundary	

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Revision	Date	Description

Paper Size: A2

Scale: 1:1250/500

Revision: 1st

Sep-15

Drawn By/Checked By: AP/HW

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Site Address:
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Location & Block Plans

Drawing Number: HR28-1005

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APPENDIX C

28 HARLEY ROAD, LONDON NW3

OUTLINE DESIGNS FOR RETAINING WALL AND SLAB

INTRODUCTION

PRELIMINARY DESIGN FOR RETAINING WALLS.

CARRY OUT TWO DESIGNS FOR WALL, ONE WITH FULL DEAD AND LIVE LOADS AND ONE WITH MINIMUM DEAD LOAD.

LOADS TO HEAD OF RETAINING WALL –

FULL DEAD PLUS LIVE

				Dead	Live	
Roof;	Dead;	$w_{dpr} = 0.5 \times 5.7\ m \times 0.95\ kN/m^2$	=	**2.7**		kN/m
	Live;	$w_{lpr} = 0.5 \times 5.7\ m \times 0.75\ kN/m^2$	=		**2.1**	kN/m
Second Floor;	Dead;	$w_{df2} = 0.5 \times 5.7\ m \times 0.65\ kN/m^2$	=	**1.9**		kN/m
	Live;	$w_{lf2} = 0.5 \times 5.7\ m \times 1.50\ kN/m^2$	=		**4.3**	kN/m
First Floor;	Dead;	$w_{df1} = 0.5 \times 5.7\ m \times 0.65\ kN/m^2$	=	**1.9**		kN/m
	Live;	$w_{lf1} = 0.5 \times 5.7\ m \times 1.50\ kN/m^2$	=		**4.3**	kN/m
Ground Floor;	Dead;	$w_{dfg} = 0.5 \times 5.7\ m \times 4.50\ kN/m^2$	=	**12.8**		kN/m
	Live;	$w_{lfg} = 0.5 \times 5.7\ m \times 1.50\ kN/m^2$	=		**4.3**	kN/m
9” Wall;	Dead;	$w_{dw9} = 3.2\ m \times 4.9\ kN/m^2$	=	**15.7**		kN/m
13½” Wall;	Dead;	$w_{dw13} = 3.9\ m \times 7.6\ kN/m^2$	=	**29.6**		kN/m

Totals; Dead; $W_d = w_{dpr} + w_{df2} + w_{df1} + w_{dfg} + w_{dw9} + w_{dw13} =$ **64.6** kN/m

Live; $W_l = w_{lpr} + w_{lf2} + w_{lf1} + w_{lfg} =$ **15.0** kN/m

MINIMUM DEAD

9” Wall;	Dead;	$w_{dw9} = 3.2\ m \times 4.9\ kN/m^2$	=	**15.7**	kN/m
13½” Wall;	Dead;	$w_{dw13} = 3.9\ m \times 7.6\ kN/m^2$	=	**29.6**	kN/m
Less windows	Dead;	$w_{wind9} = (9\ m^2 \times 4.9\ kN/m^2\ ) / 2.8\ m$	=	**15.8**	kN/m
	Dead;	$w_{wind13} = (13\ m^2 \times 7.9\ kN/m^2\ ) / 7.5\ m$	=	**13.7**	kN/m

Totals; Dead; $W_d = w_{dw9} + w_{dw13} - w_{wind9} - w_{wind13} =$ **15.9** kN/m

RETAINING WALL DESIGN CASE 1

RETAINING WALL ANALYSIS

In accordance with EN1997-1:2004 incorporating Corrigendum dated February 2009 and the UK National Annex incorporating Corrigendum No.1

Tedds calculation version 2.6.05

Retaining wall details

Stem type; Cantilever

Stem height; $h_{stem} =$ **3000** mm

Stem thickness; t_{stem} = **350** mm

Angle to rear face of stem; α = **90** deg

Stem density; γ_{stem} = **25** kN/m^3

Toe length; l_{toe} = **2500** mm

Base thickness; t_{base} = **350** mm

Base density; γ_{base} = **25** kN/m^3

Height of retained soil; h_{ret} = **3000** mm; Angle of soil surface; β = **0** deg

Depth of cover; d_{cover} = **0** mm

Height of water; h_{water} = **2200** mm

Water density; γ_w = **9.8** kN/m^3

Retained soil properties

Soil type; Firm clay

Moist density; γ_{mr} = **18** kN/m^3

Saturated density; γ_{sr} = **18** kN/m^3

Characteristic effective shear resistance angle; $\phi'_{r.k}$ = **18** deg

Characteristic wall friction angle; $\delta_{r.k}$ = **9** deg

Base soil properties

Soil type; Firm clay

Soil density; γ_b = **18** kN/m^3

Characteristic effective shear resistance angle; $\phi'_{b.k}$ = **18** deg

Characteristic wall friction angle; $\delta_{b.k}$ = **9** deg

Characteristic base friction angle; $\delta_{bb.k}$ = **12** deg

Presumed bearing capacity; $P_{bearing}$ = **125** kN/m^2

Loading details

Variable surcharge load; $Surcharge_Q$ = **2.5** kN/m^2

Vertical line load at 2700 mm; P_{G1} = **65** kN/m

; P_{Q1} = **15** kN/m

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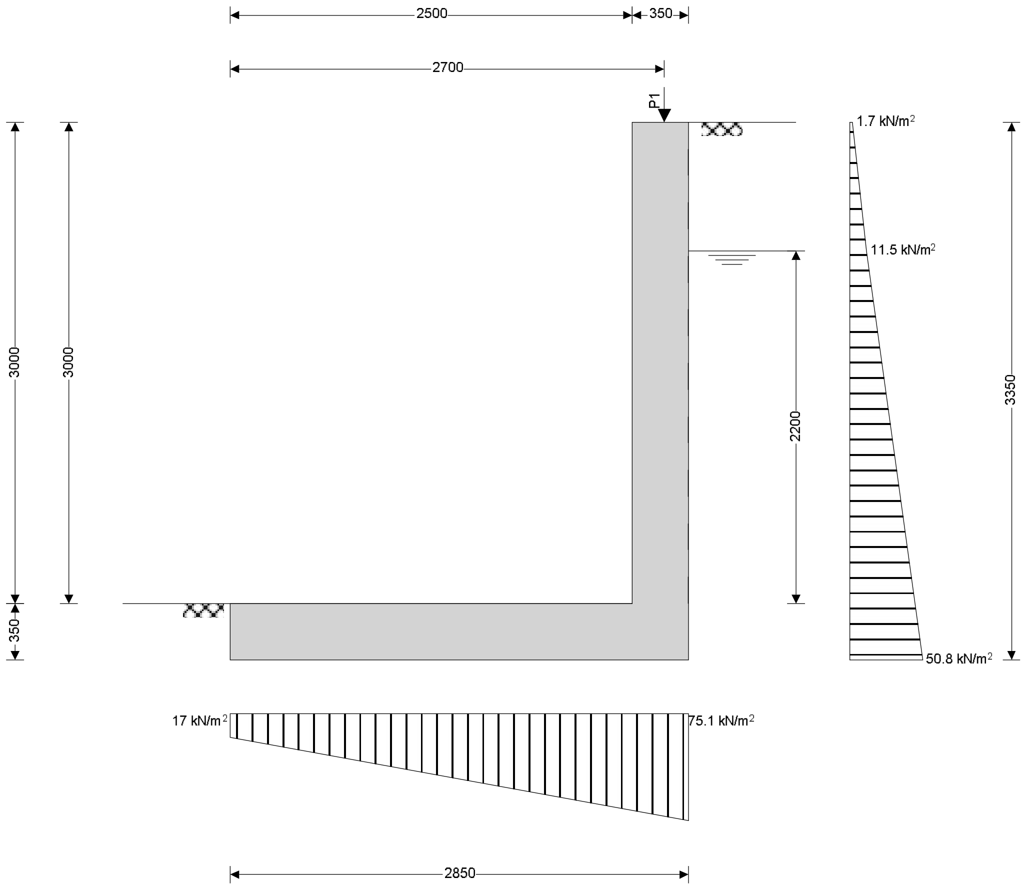
Date	Eng	Job No	Sheet No	Rev
Mar 16	DM	15189	3	

Project:
28 HARLEY ROAD
LONDON NW3



Calculate retaining wall geometry

Base length; l_{base} = **2850** mm

Saturated soil height; h_{sat} = **2200** mm

Moist soil height; h_{moist} = **800** mm

Length of surcharge load; l_{sur} = **0** mm

Vertical distance; x_{sur_v} = **2850** mm

Effective height of wall; h_{eff} = **3350** mm

Horizontal distance; x_{sur_h} = **1675** mm

Area of wall stem; A_{stem} = **1.05** m^2; Vertical distance; x_{stem} = **2675** mm

Area of wall base; A_{base} = **0.998** m^2; Vertical distance; x_{base} = **1425** mm

Using Coulomb theory

At rest pressure coefficient; K_0 = **0.691**; Passive pressure coefficient; K_P = **2.359**

Bearing pressure check

Vertical forces on wall

Total; $F_{total\_v} = F_{stem} + F_{base} + F_{water\_v} + F_{P\_v}$ = **131.2** kN/m

Horizontal forces on wall

Total; $F_{total\_h} = F_{sat\_h} + F_{moist\_h} + F_{pass\_h} + F_{water\_h} + F_{sur\_h} - F_{total\_v} \times \tan(\delta_{bb.d})$ = **54.3** kN/m

Moments on wall

Total; $M_{total} = M_{stem} + M_{base} + M_{sat} + M_{moist} + M_{pass} + M_{water} + M_{sur} + M_P$ = **226.3** kNm/m

Check bearing pressure

Bearing pressure at toe; q_{toe} = **17** kN/m^2; Bearing pressure at heel; q_{heel} = **75.1** kN/m^2

Factor of safety; FoS_{bp} = **1.664**

PASS - Allowable bearing pressure exceeds maximum applied bearing pressure

Partial factors on actions - Table A.3 - Combination 1

Permanent unfavourable action; γ_G = **1.35**; Permanent favourable action; γ_{Gf} = **1.00**

Variable unfavourable action; γ_Q = **1.50**; Variable favourable action; γ_{Qf} = **0.00**

;**Partial factors for soil parameters – Table A.4 - Combination 1**

Angle of shearing resistance; $\gamma_{\phi'}$ = **1.00**; Effective cohesion;$\gamma_{c'}$ = **1.00**

Weight density; γ_γ = **1.00**

;**Water properties**

Design water density; γ_w' = **9.8** kN/m^3

;**Retained soil properties**

Design moist density; γ_{mr}' = **18** kN/m^3; Design saturated density; γ_{sr}' = **18** kN/m^3

Des.eff.shear resist.angle; $\phi'_{r.d}$ = **18** deg; Design wall friction angle; $\delta_{r.d}$ = **9** deg

Base soil properties

Design soil density; γ_b' = **18** kN/m^3; Des.eff.shear resist.angle; $\phi'_{b.d}$ = **18** deg

Design wall friction angle; $\delta_{b.d}$ = **9** deg; Design base friction angle; $\delta_{bb.d}$ = **12** deg

;Design effective cohesion; $c'_{b.d}$ = **0** kN/m^2

Overturning check

Vertical forces on wall

Total; $F_{total\_v} = F_{stem} + F_{base} + F_{water\_v} + F_{P\_v}$ = **116.2** kN/m

Horizontal forces on wall

Total; $F_{total\_h} = F_{sat\_h} + F_{moist\_h} + F_{exc\_h} + F_{water\_h} + F_{sur\_h}$ = **112.7** kN/m

Overturning moments on wall

Total; $M_{total\_OT} = M_{sat\_OT} + M_{moist\_OT} + M_{water\_OT} + M_{sur\_OT}$ = **129.9** kNm/m

Restoring moments on wall

Total; $M_{total\_R} = M_{stem\_R} + M_{base\_R} + M_{exc\_R} + M_{P\_R}$ = **281.6** kNm/m

Check stability against overturning

Factor of safety; FoS_{ot} = **2.168**

PASS - Maximum restoring moment is greater than overturning moment

Partial factors on actions - Table A.3 - Combination 2

Permanent unfavourable action; γ_G = **1.00**; Permanent favourable action; γ_{Gf} = **1.00**

Variable unfavourable action; γ_Q = **1.30**; Variable favourable action; γ_{Qf} = **0.00**

;**Partial factors for soil parameters – Table A.4 - Combination 2**

Angle of shearing resistance; $\gamma_{\phi'}$ = **1.25**; Effective cohesion; $\gamma_{c'}$ = **1.25**

Weight density; γ_{γ} = **1.00**

Water properties

Design water density; γ_w' = **9.8** kN/m^3

Retained soil properties

Design moist density; γ_{mr}' = **18** kN/m^3; Design saturated density; γ_{sr}' = **18** kN/m^3

Des.eff.shear resist.angle; $\phi'_{r.d}$ = **14.6** deg; Design wall friction angle; $\delta_{r.d}$ = **7.2** deg

Base soil properties

Design soil density; γ_b' = **18** kN/m^3; Des.eff.shear resist.angle; $\phi'_{b.d}$ = **14.6** deg

Design wall friction angle; $\delta_{b.d}$ = **7.2** deg; Design base friction angle; $\delta_{bb.d}$ = **9.7** deg

Design effective cohesion; $c'_{b.d}$ = **0** kN/m^2

Using Coulomb theory

At rest pressure coefficient; K_0 = **0.748**; Passive pressure coefficient; K_P = **1.965**

Overturning check

Vertical forces on wall

Total; $F_{total\_v} = F_{stem} + F_{base} + F_{water\_v} + F_{P\_v}$ = **116.2** kN/m

Horizontal forces on wall

Total; $F_{total\_h} = F_{sat\_h} + F_{moist\_h} + F_{exc\_h} + F_{water\_h} + F_{sur\_h}$ = **89.1** kN/m

Overturning moments on wall

Total; $M_{total\_OT} = M_{sat\_OT} + M_{moist\_OT} + M_{water\_OT} + M_{sur\_OT}$ = **104.3** kNm/m

Restoring moments on wall

Total; $M_{total\_R} = M_{stem\_R} + M_{base\_R} + M_{exc\_R} + M_{P\_R}$ = **281.5** kNm/m

Check stability against overturning

Factor of safety; FoS_{ot} = **2.7**

PASS - Maximum restoring moment is greater than overturning moment

<u>**RETAINING WALL DESIGN**</u>

In accordance with EN1992-1-1:2004 incorporating Corrigendum dated January 2008 and the UK National Annex incorporating National Amendment No.1

Tedds calculation version 2.6.05

Concrete details - Table 3.1 - Strength and deformation characteristics for concrete

Concrete strength class; C30/37

Char.comp.cylinder strength; f_{ck} = **30** N/mm^2; Mean axial tensile strength; f_{ctm} = **2.9** N/mm^2

Secant modulus of elasticity; E_{cm} = **32837** N/mm^2; Maximum aggregate size; h_{agg} = **20** mm

Design comp.concrete strength; f_{cd} = **17.0** N/mm^2; Partial factor; γ_C = **1.50**

Reinforcement details

Characteristic yield strength; f_{yk} = **500** N/mm^2; Modulus of elasticity; E_s = **200000** N/mm^2

Design yield strength; f_{yd} = **435** N/mm^2; Partial factor; γ_S = **1.15**

Cover to reinforcement

Front face of stem; c_{sf} = **40** mm; Rear face of stem; c_{sr} = **50** mm

Top face of base; c_{bt} = **50** mm; Bottom face of base; c_{bb} = **75** mm

Check stem design at base of stem

Depth of section; h = **350** mm

Rectangular section in flexure - Section 6.1

Design bending moment; M = **93.6** kNm/m; K = **0.037**; K' = **0.207**

K' > K - No compression reinforcement is required

Tens.reinforcement required; $A_{sr.req}$ = **781** mm^2/m

Tens.reinforcement provided; 20 dia.bars @ 200 c/c; Tens.reinforcement provided; $A_{sr.prov}$ = **1571** mm^2/m

Min.area of reinforcement; $A_{sr.min}$ = **437** mm^2/m; Max.area of reinforcement; $A_{sr.max}$ = **14000** mm^2/m

PASS - Area of reinforcement provided is greater than area of reinforcement required

Crack control - Section 7.3

Limiting crack width; w_{max} = **0.3** mm; Maximum crack width; w_k = **0.18** mm

PASS - Maximum crack width is less than limiting crack width**Rectangular section in shear - Section 6.2**

Design shear force; V = **92.5** kN/m; Design shear resistance; $V_{Rd.c}$ = **161.3** kN/m

PASS - Design shear resistance exceeds design shear force

Horizontal reinforcement parallel to face of stem - Section 9.6

Min.area of reinforcement; $A_{sx.req}$ = **393** mm^2/m; Max.spacing of reinforcement;s_{sx_max} = **400** mm

Trans.reinforcement provided; 10 dia.bars @ 200 c/c; Trans.reinforcement provided; $A_{sx.prov}$ = **393** mm^2/m

PASS - Area of reinforcement provided is greater than area of reinforcement required

Check base design at toe

Depth of section; h = **350** mm

Rectangular section in flexure - Section 6.1

Design bending moment; M = **107.3** kNm/m; K = **0.049**; K' = **0.207**

K' > K - No compression reinforcement is required

Tens.reinforcement required; $A_{bb.req}$ = **966** mm^2/m

Tens.reinforcement provided; 20 dia.bars @ 200 c/c; Tens.reinforcement provided; $A_{sr.prov}$ = **1571** mm^2/m

Min.area of reinforcement; $A_{sr.min}$ = **437** mm^2/m; Max.area of reinforcement; $A_{sr.max}$ = **14000** mm^2/m

PASS - Area of reinforcement provided is greater than area of reinforcement required

Design shear force; V = **115.4** kN/m; Design shear resistance; $V_{Rd.c}$ = **131.1** kN/m

PASS - Design shear resistance exceeds design shear force

Secondary transverse reinforcement to base - Section 9.3

Min.area of reinforcement; $A_{bx.req}$ = **113** mm^2/m; Max.spacing of reinforcement;s_{bx_max} = **450** mm

Trans.reinforcement provided; 10 dia.bars @ 200 c/c; Trans.reinforcement provided;$A_{bx.prov}$ = **393** mm^2/m

PASS - Area of reinforcement provided is greater than area of reinforcement required

RETAINING WALL DESIGN CASE 2

RETAINING WALL ANALYSIS

In accordance with EN1997-1:2004 incorporating Corrigendum dated February 2009 and the UK National Annex incorporating Corrigendum No.1

Tedds calculation version 2.6.05

Retaining wall details

Stem type; Cantilever

Stem height; h_{stem} = **3000** mm

Stem thickness; t_{stem} = **350** mm

Angle to rear face of stem; α = **90** deg

Stem density; γ_{stem} = **25** kN/m^3

Toe length; l_{toe} = **2500** mm

Base thickness; t_{base} = **350** mm

Base density; γ_{base} = **25** kN/m^3

Height of retained soil; h_{ret} = **3000** mm; Angle of soil surface; β = **0** deg

Depth of cover; d_{cover} = **0** mm

Height of water; h_{water} = **2200** mm

Water density; γ_w = **9.8** kN/m^3

Retained soil properties

Soil type; Firm clay

Moist density; γ_{mr} = **18** kN/m^3

Saturated density; γ_{sr} = **18** kN/m^3

Characteristic effective shear resistance angle; $\phi'_{r.k}$ = **18** deg

Characteristic wall friction angle; $\delta_{r.k}$ = **9** deg

Base soil properties

Soil type; Firm clay

Soil density; γ_b = **18** kN/m^3

Characteristic effective shear resistance angle; $\phi'_{b.k}$ = **18** deg

Characteristic wall friction angle; $\delta_{b.k}$ = **9** deg

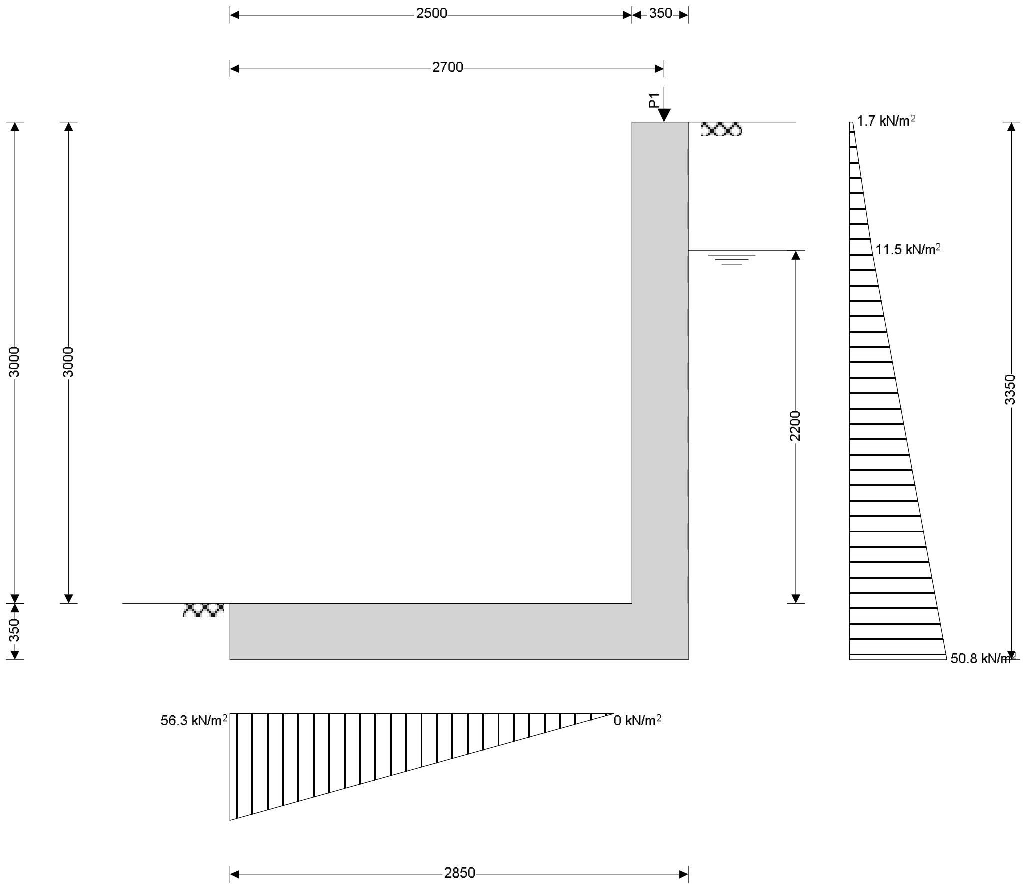
Characteristic base friction angle; $\delta_{bb.k}$ = **12** deg

Presumed bearing capacity; $P_{bearing}$ = **125** kN/m^2

Loading details

Variable surcharge load; $Surcharge_Q$ = **2.5** kN/m^2

Vertical line load at 2700 mm; P_{G1} = **16** kN/m



Calculate retaining wall geometry

Base length; l_{base} = **2850** mm

Saturated soil height; h_{sat} = **2200** mm

Moist soil height; h_{moist} = **800** mm

Length of surcharge load; l_{sur} = **0** mm

Vertical distance; x_{sur_v} = **2850** mm

Effective height of wall; h_{eff} = **3350** mm

Horizontal distance; x_{sur_h} = **1675** mm

Area of wall stem; A_{stem} = **1.05** m^2; Vertical distance; x_{stem} = **2675** mm

Area of wall base; A_{base} = **0.998** m^2; Vertical distance; x_{base} = **1425** mm

Using Coulomb theory

At rest pressure coefficient; K_0 = **0.691**; Passive pressure coefficient; K_P = **2.359**

Bearing pressure check

Vertical forces on wall

Total; $F_{total\_v} = F_{stem} + F_{base} + F_{water\_v} + F_{P\_v}$ = **67.2** kN/m

Horizontal forces on wall

Total; $F_{total\_h} = F_{sat\_h} + F_{moist\_h} + F_{pass\_h} + F_{water\_h} + F_{sur\_h} - F_{total\_v} \times \tan(\delta_{bb.d})$ = **67.9** kN/m

Moments on wall

Total; $M_{total} = M_{stem} + M_{base} + M_{sat} + M_{moist} + M_{pass} + M_{water} + M_{sur} + M_P$ = **53.5** kNm/m

Check bearing pressure

Bearing pressure at toe; q_{toe} = **56.3** kN/m^2; Bearing pressure at heel; q_{heel} = **0** kN/m^2

Factor of safety; FoS_{bp} = **2.222**

PASS - Allowable bearing pressure exceeds maximum applied bearing pressure

Partial factors on actions - Table A.3 - Combination 1

Permanent unfavourable action; γ_G = **1.35**; Permanent favourable action; γ_{Gf} = **1.00**

Variable unfavourable action; γ_Q = **1.50**; Variable favourable action; γ_{Qf} = **0.00**

;**Partial factors for soil parameters – Table A.4 - Combination 1**

Angle of shearing resistance; $\gamma_{\phi'}$ = **1.00**; Effective cohesion;$\gamma_{c'}$ = **1.00**

Weight density; γ_γ = **1.00**

;**Water properties**

Design water density; γ_w' = **9.8** kN/m^3

;**Retained soil properties**

Design moist density; γ_{mr}' = **18** kN/m^3; Design saturated density; γ_{sr}' = **18** kN/m^3

Des.eff.shear resist.angle; $\phi'_{r.d}$ = **18** deg; Design wall friction angle; $\delta_{r.d}$ = **9** deg

Base soil properties

Design soil density; γ_b' = **18** kN/m^3; Des.eff.shear resist.angle; $\phi'_{b.d}$ = **18** deg

Design wall friction angle; $\delta_{b.d}$ = **9** deg; Design base friction angle; $\delta_{bb.d}$ = **12** deg

;Design effective cohesion;$c'_{b.d}$ = **0** kN/m^2

Using Coulomb theory

At rest pressure coefficient; K_0 = **0.691**; Passive pressure coefficient;K_P = **2.359**

Overturning check

Vertical forces on wall

Total; $F_{total\_v} = F_{stem} + F_{base} + F_{water\_v} + F_{P\_v}$ = **67.2** kN/m

Horizontal forces on wall

Total; $F_{total\_h} = F_{sat\_h} + F_{moist\_h} + F_{exc\_h} + F_{water\_h} + F_{sur\_h}$ = **112.7** kN/m

Overturning moments on wall

Total; $M_{total\_OT} = M_{sat\_OT} + M_{moist\_OT} + M_{water\_OT} + M_{sur\_OT}$ = **129.9** kNm/m

Restoring moments on wall

Total; $M_{total\_R} = M_{stem\_R} + M_{base\_R} + M_{exc\_R} + M_{P\_R}$ = **149.3** kNm/m

Check stability against overturning

Factor of safety; FoS_{ot} = **1.149**

PASS - Maximum restoring moment is greater than overturning moment

Partial factors on actions - Table A.3 - Combination 2

Permanent unfavourable action; γ_G = **1.00**; Permanent favourable action; γ_{Gf} = **1.00**

Variable unfavourable action; γ_Q = **1.30**; Variable favourable action; γ_{Qf} = **0.00**

;**Partial factors for soil parameters – Table A.4 - Combination 2**

Angle of shearing resistance; $\gamma_{\phi'}$ = **1.25**; Effective cohesion;$\gamma_{c'}$ = **1.25**

Weight density; γ_γ = **1.00**

;**Water properties**

Design water density; γ_w' = **9.8** kN/m^3

;**Retained soil properties**

Design moist density; γ_{mr}' = **18** kN/m^3; Design saturated density; γ_{sr}' = **18** kN/m^3

Des.eff.shear resist.angle; $\phi'_{r.d}$ = **14.6** deg; Design wall friction angle; $\delta_{r.d}$ = **7.2** deg

Base soil properties

Design soil density; γ_b' = **18** kN/m^3; Des.eff.shear resist.angle; $\phi'_{b.d}$ = **14.6** deg

Design wall friction angle; $\delta_{b.d}$ = **7.2** deg; Design base friction angle; $\delta_{bb.d}$ = **9.7** deg

;Design effective cohesion;$c'_{b.d}$ = **0** kN/m^2

Using Coulomb theory

At rest pressure coefficient; K_0 = **0.748**; Passive pressure coefficient;K_P = **1.965**

Overturning check

Vertical forces on wall

Total; $F_{total\_v} = F_{stem} + F_{base} + F_{water\_v} + F_{P\_v}$ = **67.2** kN/m

Horizontal forces on wall

Total; $F_{total\_h} = F_{sat\_h} + F_{moist\_h} + F_{exc\_h} + F_{water\_h} + F_{sur\_h}$ = **89.1** kN/m

Overturning moments on wall

Total; $M_{total\_OT} = M_{sat\_OT} + M_{moist\_OT} + M_{water\_OT} + M_{sur\_OT}$ = **104.3** kNm/m

Restoring moments on wall

Total; $M_{total\_R} = M_{stem\_R} + M_{base\_R} + M_{exc\_R} + M_{P\_R}$ = **149.2** kNm/m

Check stability against overturning

Factor of safety; FoS_{ot} = **1.431**

PASS - Maximum restoring moment is greater than overturning moment

RETAINING WALL DESIGN

In accordance with EN1992-1-1:2004 incorporating Corrigendum dated January 2008 and the UK National Annex incorporating National Amendment No.1

Tedds calculation version 2.6.05

Concrete details - Table 3.1 - Strength and deformation characteristics for concrete

Concrete strength class; C30/37

Char.comp.cylinder strength; f_{ck} = **30** N/mm^2; Mean axial tensile strength; f_{ctm} = **2.9** N/mm^2

Secant modulus of elasticity; E_{cm} = **32837** N/mm^2; Maximum aggregate size; h_{agg} = **20** mm

Design comp.concrete strength; f_{cd} = **17.0** N/mm^2; Partial factor;γ_C = **1.50**

Reinforcement details

Characteristic yield strength; f_{yk} = **500** N/mm^2; Modulus of elasticity; E_s = **200000** N/mm^2

Design yield strength; f_{yd} = **435** N/mm^2; Partial factor; γ_S = **1.15**

Cover to reinforcement

Front face of stem; c_{sf} = **40** mm; Rear face of stem; c_{sr} = **50** mm

Top face of base; c_{bt} = **50** mm; Bottom face of base; c_{bb} = **75** mm

Check stem design at base of stem

Depth of section; h = **350** mm

Rectangular section in flexure - Section 6.1

Design bending moment; M = **93.6** kNm/m; K = **0.037**; K' = **0.207**

K' > K - No compression reinforcement is required

Tens.reinforcement required; $A_{sr.req}$ = **781** mm^2/m

Tens.reinforcement provided; 20 dia.bars @ 200 c/c; Tens.reinforcement provided; $A_{sr.prov}$ = **1571** mm^2/m

Min.area of reinforcement; $A_{sr.min}$ = **437** mm^2/m; Max.area of reinforcement; $A_{sr.max}$ = **14000** mm^2/m

PASS - Area of reinforcement provided is greater than area of reinforcement required

Crack control - Section 7.3

Limiting crack width; w_{max} = **0.3** mm; Maximum crack width; w_k = **0.18** mm

PASS - Maximum crack width is less than limiting crack width**Rectangular section in shear - Section 6.2**

Design shear force; V = **92.5** kN/m; Design shear resistance; $V_{Rd.c}$ = **161.3** kN/m

PASS - Design shear resistance exceeds design shear force

Horizontal reinforcement parallel to face of stem - Section 9.6

Min.area of reinforcement; $A_{sx.req}$ = **393** mm^2/m; Max.spacing of reinforcement;s_{sx_max} = **400** mm

Trans.reinforcement provided; 10 dia.bars @ 200 c/c; Trans.reinforcement provided; $A_{sx.prov}$ = **393** mm^2/m

PASS - Area of reinforcement provided is greater than area of reinforcement required

Check base design at toe

Depth of section; h = **350** mm

Rectangular section in flexure - Section 6.1

Design bending moment; M = **119** kNm/m; K = **0.055**; K' = **0.207**

K' > K - No compression reinforcement is required

Tens.reinforcement required; $A_{bb.req}$ = **1072** mm^2/m

Tens.reinforcement provided; 20 dia.bars @ 200 c/c; Tens.reinforcement provided; $A_{sr.prov}$ = **1571** mm^2/m

Min.area of reinforcement; $A_{sr.min}$ = **437** mm^2/m; Max.area of reinforcement; $A_{sr.max}$ = **14000** mm^2/m

PASS - Area of reinforcement provided is greater than area of reinforcement required

Design shear force; V = **61.2** kN/m; Design shear resistance; $V_{Rd.c}$ = **131.1** kN/m

PASS - Design shear resistance exceeds design shear force

Secondary transverse reinforcement to base - Section 9.3

Min.area of reinforcement; $A_{bx.req}$ = **113** mm^2/m; Max.spacing of reinforcement;s_{bx_max} = **450** mm

Trans.reinforcement provided; 10 dia.bars @ 200 c/c; Trans.reinforcement provided; $A_{bx.prov}$ = **393** mm^2/m

PASS - Area of reinforcement provided is greater than area of reinforcement required