GROUND MOVEMENT ASSESSMENT REPORT

The Bull & Last PH
168 Highgate Road
London NW5

Client: Oliver Pudney / Etive Pubs Limited

Engineer: Michael Alexander Consulting Engineers

J15145

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GEA Geotechnical & Environmental Associates

Document Control

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1.0 INTRODUCTION

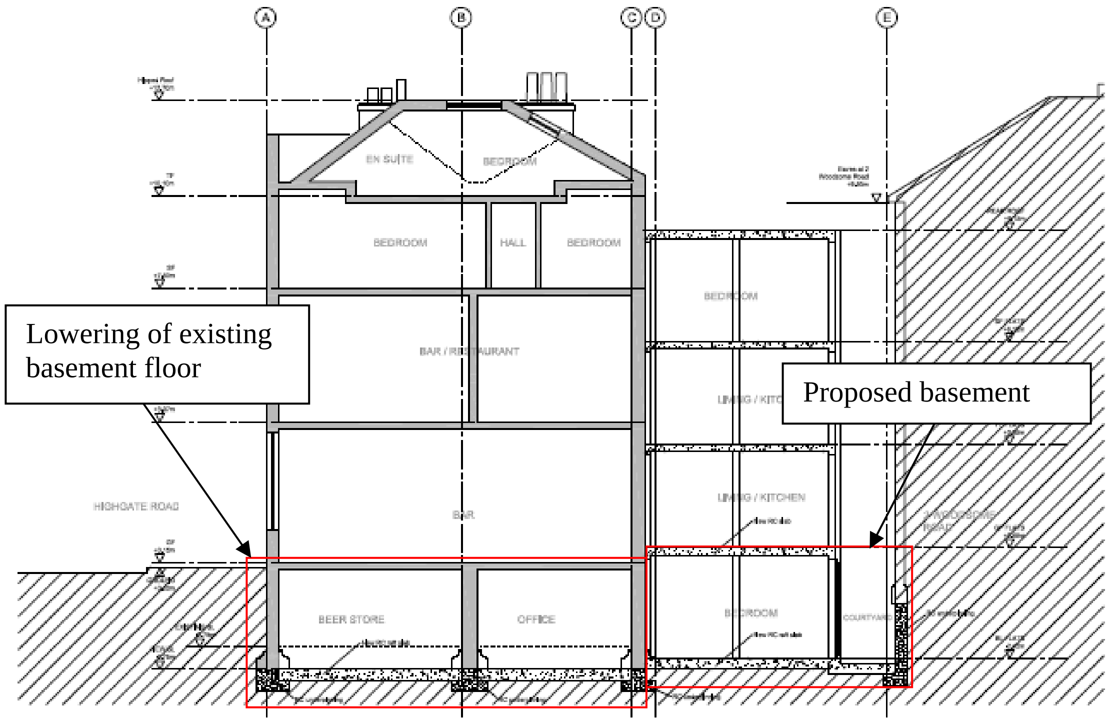
Geotechnical and Environmental Associates (GEA) has been commissioned by Michael Alexander Consulting Engineers, on behalf of Oliver Pudney / Etive Pubs Ltd, to carry out a ground movement analysis and building damage assessment at The Bull and Last Public House, 168 Highgate Road, London, NW5 1QS.

A Desk Study and Ground Investigation has previously been carried out by GEA (report ref J15145, dated July 2015), the findings of which have been used in the derivation of parameters for use in this assessment.

The purpose of this assessment has been to determine the effects of the demolition of the existing extension and proposed basement construction upon the neighbouring structures.

1.1 Proposed Development

It is proposed to lower the existing basement slab by approximately 600 mm in order to improve the head height for future use of the basement- as a kitchen. In addition, it is proposed to demolish the existing single storey kitchen and construct a new three-storey house with a single level basement.



It is understood that the consulting engineer is favouring the installation of underpins to support the existing and proposed basement.

This report is specific to the proposed development and the advice herein should be reviewed if the development proposals are amended.

1.2 Limitations

The conclusions and recommendations made in this report are limited to those that can be made on the basis of the investigation. The results of the work should be viewed in the context of the range of data sources consulted, the number of locations where the ground was sampled and the number of soil, gas or groundwater samples tested; no liability can be accepted for information in other data sources or conditions not revealed by the sampling or testing. Any comments made on the basis of information obtained from the client or other third parties are given in good faith on the assumption that the information is accurate; no independent validation of such information has been made by GEA.

2.0 THE SITE

2.1 Site Description

The site is located in the London Borough of Camden, on the eastern side of Parliament Hill, roughly 900 m to the northwest of Tuffnell Park London Underground Station. It is roughly rectangular in shape, measuring approximately 15 m by 20 m. It is on a corner plot, bounded by Highgate Road to the west and Woodsome Road to the south and is adjoined to the north by a three-storey terraced house and bounded to the east by a three-storey end of terrace house. The site may be additionally located by National Grid Reference 528440, 186070.

The site is currently occupied by the Bull and Last Public House; a three-storey building with a single level basement and a single-storey extension along the eastern elevation. A courtyard is present in the east of the site at ground level, which is essentially used for the storage of bins and to provide access for deliveries.

The local topography slopes down generally towards the south. The site is essentially on a level plot at an elevation of about 55.8 m OD, with the exception of the courtyard which slopes down towards the north.

The site is devoid of vegetation.

2.2 Previous Exploratory Work

The previous GEA site investigation consisted of a single cable percussion borehole advanced to a depth of 12.00 m from ground level in the courtyard, using a dismantlable cable percussion rig. Standard Penetration Tests (SPTs) were carried out at regular intervals in the cable percussion borehole to provide quantitative data on the strength of soils encountered.

To supplement the cable percussion borehole, a single drive-in window sampler borehole was advanced to a depth of 5.50 m from existing basement level.

Groundwater monitoring standpipes were installed in both boreholes to depths of 5.20 m and 6.00 m and have been monitored on two occasions to date, roughly two and three weeks after installation.

A total of two trial pits was manually excavated to investigate the foundations of the existing basement and boundary wall.

3.0 SUMMARY OF GROUND CONDITIONS

The investigation generally encountered the expected ground conditions in that, beneath a moderate to relatively significant thickness of made ground, London Clay was encountered to the full depth of the investigation.

The greatest thickness of made ground of 2 m was encountered in close proximity to a deep drain at ground level.

The London Clay comprised firm becoming stiff fissured medium strength becoming high strength brown mottled grey silty fissured clay with occasional partings of orange-brown fine sand and silt and selenite crystals, which extended to a depth of 11.55 m, overlying stiff grey fissured silty clay, proved to the maximum depth investigated of 12.00 m below ground level. Decaying plant remains were noted at a depth of 1.55 m below existing basement level; although desiccation was not noted during the investigation.

Groundwater was not encountered during the investigation and subsequent monitoring of the two installed standpipes has found them to be dry on two occasions to date.

Atterberg limit tests indicate the clay to be of high volume change potential.

The results of the undrained triaxial tests generally indicate an increase in strength with depth from 72 kN/m² at a depth of 2.00 m to 141 kN/m² at a depth of 9.50 m. The results indicate the clay to be of medium strength to high strength.

No evidence of contamination was noted in these soils.

3.1 British Geological Survey (BGS) Archives

A review of deep borehole records held on the British Geological Survey (BGS) database, the closest of which is located approximately 100 m to the northeast of the site, has indicated that the London Clay extends to a depth of approximately 72 m, below which the Lambeth Group extends to a depth of approximately 91 m, whereafter the Thanet Sand and then Upper Chalk are found to be present.

4.0 CONSTRUCTION SEQUENCE

The following sequence of operations has been assumed to enable analysis of the ground movements around the basement both during and after construction.

In general, the sequence of works for basement construction will comprise the following stages.

1. Construct underpinned retaining walls to all boundaries, including underpins beneath the party walls with No 2 Woodsome Road and No 168 Highgate Road. These are commonly formed in a ‘hit and miss’ sequence using a trench box excavation, commonly sheet lined, shored and strutted; all temporary shoring and propping to be inspected by a suitably qualified person; and

2. excavate new basement and temporarily retain and strengthen the new retaining walls, with sufficient propping and waling beams.

The underpins should be adequately laterally propped and sufficiently dowelled together, with the concrete cast and adequately cured prior to excavation of the basement and removal of the formwork and supports.

When the final excavation depths have been reached the permanent works will be formed, which are likely to comprise reinforced concrete walls with a drained cavity lining the inside of the underpinned walls. Reinforced concrete will be used for floor slabs and heave protection may need to be installed beneath the basement slab. Following this, the floor slab will be constructed at basement level and ground floor level so that the temporary props may be removed.

The detail of the support provided to adjacent walls is beyond the scope of this report at this stage and the structural engineer will be best placed to agree a methodology with the underpinning contractors once appointed.

5.0 GROUND MOVEMENTS

An assessment of ground movements within and surrounding the excavation has been undertaken using the X-Disp and P-Disp computer programs licensed from the OASYS suite of geotechnical modelling software from Arup. These programs are commonly used within the ground engineering industry and are considered to be appropriate tools for this analysis.

The X-Disp program has been used to predict ground movements likely to arise from the construction of the proposed basement. This includes the settlement of the ground (vertical movement) and the lateral movement of soil behind the proposed retaining walls (horizontal movement).

The analysis of potential ground movements within the excavation, as a result of unloading of the underlying soils, has been carried out using the Oasys P-Disp Version 19.3 – Build 12 software package and is based on the assumption that the soils behave elastically, which provides a reasonable approximation to soil behaviour at small strains.

For the purpose of these analyses, the corners have been defined by x and y coordinates, with the x-direction parallel with the orientation northeast-southwest, whilst the y-direction is parallel with the orientation of northwest-southeast. Vertical movement is in the z-direction.

The full outputs of all the analyses can be provided on request but samples of the output movement contour plots are included within the appendix.

5.1 Ground Movements – Surrounding the Basement

5.1.1 Model Used

For the X-Disp analysis, the soil movement relationships used for the embedded retaining walls are the default values within CIRIA report C580[1], which were derived from a number of historic case studies.

The ground movement curves for 'excavations in front of high stiffness wall in clay' have been adopted as being considered most appropriate for the proposed excavation and its support at this site.

1 Gaba, A, Simpson, B, Powrie, W and Beadman, D (2003) *Embedded retaining walls – guidance for economic design* .CIRIA Report C580.

The ground movement curves for 'installation of a planar diaphragm wall in stiff clay' have been adopted as being considered most appropriate for the proposed underpin phase at this site.

Due to the complex nature of the excavation and limitations within the software, the analysis was split into two models. One modelled the lowered basement floor, which covers the basement beneath the main building, and a second modelled the deeper excavation which covers the footprint beneath the proposed three-storey house. The results of both were analysed and are presented in the section below.

The results are presented to the degree of accuracy required to allow predicted variations in ground movements around the structure(s) to be illustrated, but may not reflect the anticipated accuracy of the predictions.

5.1.2 Results

The predicted movements are based on the worst case of the individually analysed segments of 'hogging' and 'sagging' and these are summarised in the tables below.

Lowering of existing basement floor

Phase of Works	Wall Movement (mm)	
	Vertical Settlement	Horizontal Movement
Basement Excavation	<1	<1
Underpin Installation	<1	<1
Combined Movements	<1	<2

The analysis has predicted that movements will not be present at ground level, therefore the above movements are noted at existing foundation level (2.15 m depth). The analysis has indicated that the maximum vertical settlements that will result from the excavation phase are less than 1 mm, whilst any horizontal movements will be less than 1 mm. The maximum vertical settlement that will take place behind the walls as a result of the basement excavation has been shown to be less than 1 mm.

The movements arising from the combined excavation and underpin phases are therefore not likely to exceed 1 mm vertical settlement, whilst the maximum horizontal movements are also anticipated to be less than 2 mm.

The movements calculated are considered to represent a worst case scenario, particularly as the movements resulting from basement excavation will be minimised due to control of the propping in the temporary works and a regime of monitoring.

New single level basement excavation

Phase of Works	Wall Movement (mm)	
	Vertical Settlement	Horizontal Movement
Basement Excavation	2	4
Underpin Installation	<2	<2
Combined Movements	<3	5

The analysis has indicated that the maximum vertical settlements that will result from excavation are less than 5 mm, whilst any horizontal movements will also be less than 5 mm. The maximum vertical settlement that will take place behind the walls as a result of the basement excavation has generally been shown to be less than 5 mm.

The movements arising from the combined excavation and underpin phases are therefore not likely to exceed 3 mm vertical settlement, whilst the maximum horizontal movements are also anticipated to be equal to or less than 5 mm.

The estimated movements are considered to represent a worst case scenario, particularly as the movements resulting from basement excavation will be minimised due to control of the propping in the temporary works and a regime of monitoring.

5.2 Movements within the Excavation (Heave)

5.2.1 Model Used

At this site unloading of the London Clay will take place as a result of the demolition of the existing single-store kitchen and basement excavation. The reduction in vertical stress will cause heave to take place. Undrained soil parameters have been used to estimate the potential short term movements, which include the “immediate” or elastic movements as a result of the demolition of the existing building and basement excavation. Drained parameters have been used to provide an estimate of the total long-term movement.

The elastic analysis requires values of soil stiffness at various levels to calculate displacements. Values of stiffness for the soils at this site are readily available from published data and we have used a well-established method to provide our estimates. This relates values of E_u and E', the drained and undrained stiffness respectively, to values of undrained cohesion, as described by Padfield and Sharrock[2] and Butler[3] and more recently by O’Brien and Sharp[4]. Relationships of $E_u = 500\ C_u$ and $E' = 300\ C_u$ for the cohesive soils and 2000 x SPT ‘N’ for granular soils have been used to obtain values of Young’s modulus. More recent published data[5] indicates stiffness values of 750 x Cu for the London Clay and a ratio of E’ to Cu of 0.75, but it is considered that the use of the more conservative values provides a sensible approach for this stage in the design.

2 Padfield CJ and Sharrock MJ (1983) *Settlement of structures on clay soils*. CIRIA Special Publication 27

3 Butler FG (1974) *Heavily overconsolidated clays: a state of the art review*. Proc Conf Settlement of Structures, Cambridge, 531-578, Pentech Press, Lond

4 O’Brien AS and Sharp P (2001) *Settlement and heave of overconsolidated clays - a simplified non-linear method.* Part Two, Ground Engineering, Nov 2001, 48-53

5 Burland JB, Standing, JR, and Jardine, FM (2001) Building response to tunnelling, case studies from construction of the Jubilee Line Extension.. CIRIA Special Publication 200

The proposed lowering of the existing basement floor, demolition of the existing kitchen and excavation of the new basement will result in a net unloading of roughly 60 kN/m² beneath the existing kitchen footprint, and 10 kN/m² beneath the existing building footprint, assuming a unit weight of overburden soil of 19 kN/m^3.

A rigid boundary for the analysis has been set at a depth of about 70.0 m below existing ground level, where nearby BGS records indicate that the base of the London Clay is likely to be present.

5.2.2 Results

The P-Disp analysis indicates that, by the time the existing basement floor has been lowered, the existing kitchen has been demolished and basement construction is complete, up to 6 mm of heave is likely to have taken place beneath the proposed three-storey building footprint reducing to 2 mm toward the existing basement, reducing to approximately 1 mm to 2 mm at the edges.

In the long term, a further 9 mm of heave is estimated as a result of long term swelling of the underlying London Clay beneath the proposed three-storey building footprint reducing to 5 mm toward the existing basement. However due to the construction of the new three-storey building and existing basement extension it is likely not all of this further movement will be realised.

The results of the P-Disp analysis also indicate the likely impact of the proposed basement construction beyond the site boundaries. On the basis of the analysis, total vertical heave movements outside the proposed basement are unlikely to exceed 2 mm at a distance of approximately 5 m, reducing to approximately less than 1 mm at distances in excess of 10 m.

The potential movements are summarised in the table.

Location	Movement (mm)		
	Short-term Heave (Demolition and Excavation	Long-term Heave (Post Construction)	Total Heave
Centre of new build excavation	6	9	15
Edge of new build excavation	1	7	8
At 5 m from edge of excavations	<1	1	1

The above figures are based on an unrestrained excavation as the model is unable to take account of the mitigating effect of the existing structures and proposed underpins, which in reality will combine to restrict these movements within the basement excavation. The movements predicted at or just beyond the site boundaries are unlikely to be fully realised and should not therefore have a detrimental impact upon any nearby structures.

In order to mitigate the effects of heave on the new building, the basement could be designed to transmit heave forces into the underpins.

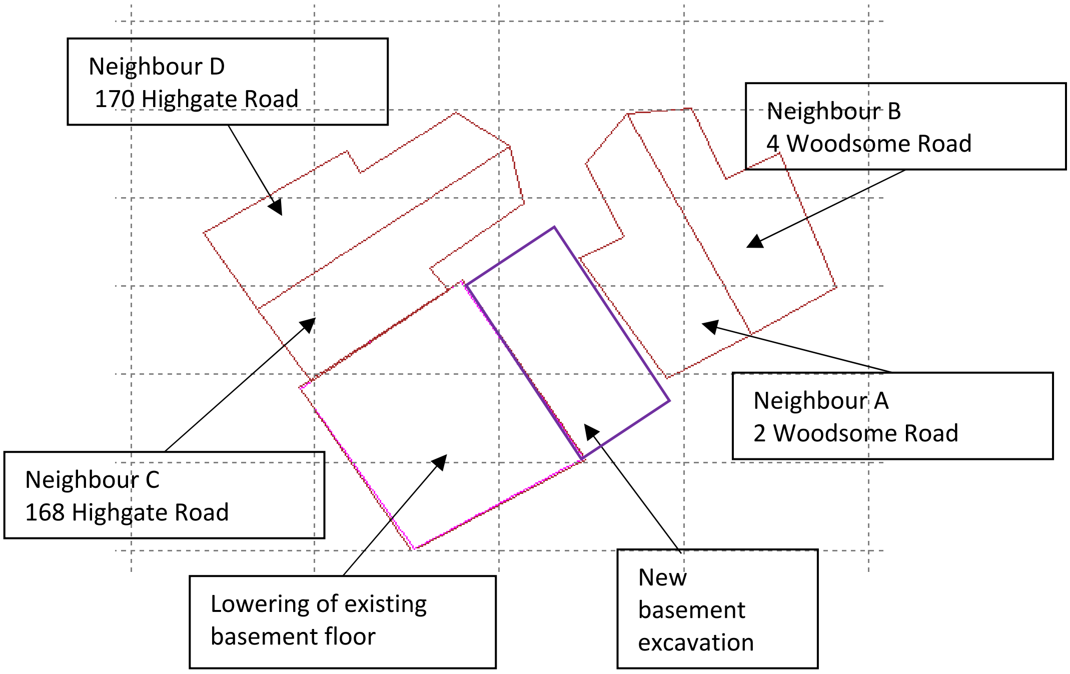
Alternatively, or in any case, a void or layer of compressible material should be incorporated into the design to accommodate these potential long term movements.

If a compressible material is used beneath the slab, it will need to be designed to be able to resist the potential uplift forces generated by the ground movements. In this respect potential heave pressures are typically taken to equate to around 30% to 40% of the total unloading pressure.

6.0 DAMAGE ASSESSMENT

In addition to the above assessment of the likely movements that will result from the proposed development, some of the neighbouring structures have been considered as sensitive structures, requiring Building Damage Assessments, on the basis of the classification given in Table 2.5 of C580[1]. These include the surrounding neighbouring properties which can be identified on the key plan in the appendix.

The sensitive structures outlined above have been modelled as lines in the analysis and are the lines along which the damage assessment has been undertaken. A plan of the sensitive structures is provided below, and a key plan detailing the specific lines is included in the Appendix.



For the purpose of the analysis ground level has been taken as level across the site, in order to keep the models consistent with each other with regard to excavation depth and assumed founding levels.

Neighbouring properties were located in the analysis by using a DWG drawing 'Planning Submission 20150617', provided by the consulting engineer. Information on neighbouring foundation levels was provided as an assumed 1.5 m depth. Furthermore, information on coal cellars present within the eastern and northern extents of 2 Woodsome Road and 168 Highgate Road respectively was provided. However as these appeared to be removed from the proposed excavations it was deemed conservative to use the shallower 1.5 m founding depth rather than a deeper assumed 1.8 m depth.

For the analyses it has been assumed that the neighbouring properties do not have basements.

6.1 Damage to Neighbouring Structures

The combined short term movements resulting from both retaining wall installation and basement excavation calculated using the X-Disp modelling software have been used to carry out an assessment of the likely damage to adjacent properties and the results are summarised in the table below. The detailed tabular output is included in the Appendix alongside a key plan for reference. As the analysis had to be split into two models, the worst case is presented overleaf.

Building Damage Assessment		
Sensitive Structure	**Elevation**	**Category of Damage***
The Bull and Last PH	Northern	1 (Very Slight)
	Eastern	0 (Negligible)
	Southern	1 (Very Slight)
	Western	0 (Negligible
Neighbour A 2 Woodsome Road	Northern 1	1 (Very Slight)
	Northern 2	0 (Negligible)
	Northern 3	0 (Negligible)
	Eastern	0 (Negligible)
	Southern	1 (Very Slight)
	Western	0 (Negligible)
Neighbour B 4 Woodsome Road	Northern 1	0 (Negligible)
	Northern 2	0 (Negligible)
	Northern 3	0 (Negligible)
	Eastern	0 (Negligible)
	Southern	0 (Negligible)
	Western	0 (Negligible)
Neighbour C 168 Highgate Road	Northern	0 (Negligible)
	Eastern 1	1 (Very Slight)
	Eastern 2	0 (Negligible)
	Eastern 3	0 (Negligible)
	Southern	1 (Very Slight)
	Western	0 (Negligible)

Building Damage Assessment		
Sensitive Structure	Elevation	Category of Damage*
Neighbour D 170 Highgate Road	Northern 1	0 (Negligible)
	Northern 2	0 (Negligible)
	Northern 3	0 (Negligible)
	Eastern	0 (Negligible)
	Southern	0 (Negligible)
	Western	0 (Negligible)

**From Table 2.5 of C580[1]: Classification of visible damage to walls.*

The building damage reports for sensitive structures highlighted in the above table predict that the damage to the neighbouring structures would generally be Category 0 (Negligible), with some limited areas of Category 1 (Very Slight) to parts of those structures closest to the proposed basement structure, which would fall within acceptable limits.

6.2 Monitoring of Ground Movements

The predictions of ground movement based on the ground movement analysis should be checked by monitoring of adjacent properties and structures. The structures to be monitored during the construction stages should include the neighbouring properties A and C.

Condition surveys of the above existing structures should be carried out before and after the proposed works.

The precise monitoring strategy will be developed at a later stage and it will be subject to discussions and agreements with the owners of the adjacent properties and structures. Contingency measures will be implemented if movements of the adjacent structures exceed predefined trigger levels. Both contingency measures and trigger levels will need to be developed within a future monitoring specification for the works.

7.0 CONCLUSIONS

The analysis has concluded that the predicted damage to the neighbouring properties would generally be ‘Negligible’, with some limited areas of ‘Very Slight’ on the walls of some neighbouring properties.). On this basis, the damage that would inevitably occur as a result of such an excavation would fall within the acceptable limits.

It is recommended that movement monitoring is carried out on all structures prior to and during the proposed basement construction.

The separate phases of work, including excavation of the proposed 2.45 m deep basement, will in practice be separated by a number of weeks during which time construction of permanent supports, basement slab and underpin curing will take place. This will provide an opportunity for the ground movements during and immediately after underpin construction to be measured and the data acquired can be fed back into the design and compared with the predicted values. Such a comparison will allow the ground model to be reviewed and the predicted wall movements to be reassessed prior to the main excavation taking place so that propping arrangements can be adjusted if required.

APPENDIX

X-DISP ANALYSIS

Basement Excavation

Contour Plots of Vertical Movements and Horizontal Movements for both Existing Basement and New Basement Analysis

Installation of underpins

Contour Plot of Vertical Movements and Horizontal Movements for both Existing Basement and New Basement Analysis

Basement Excavation and Underpin Analysis

Contour Plots of Combined Vertical Movements and Horizontal Movements for both Existing Basement and New Basement Analysis

P-DISP ANALYSIS

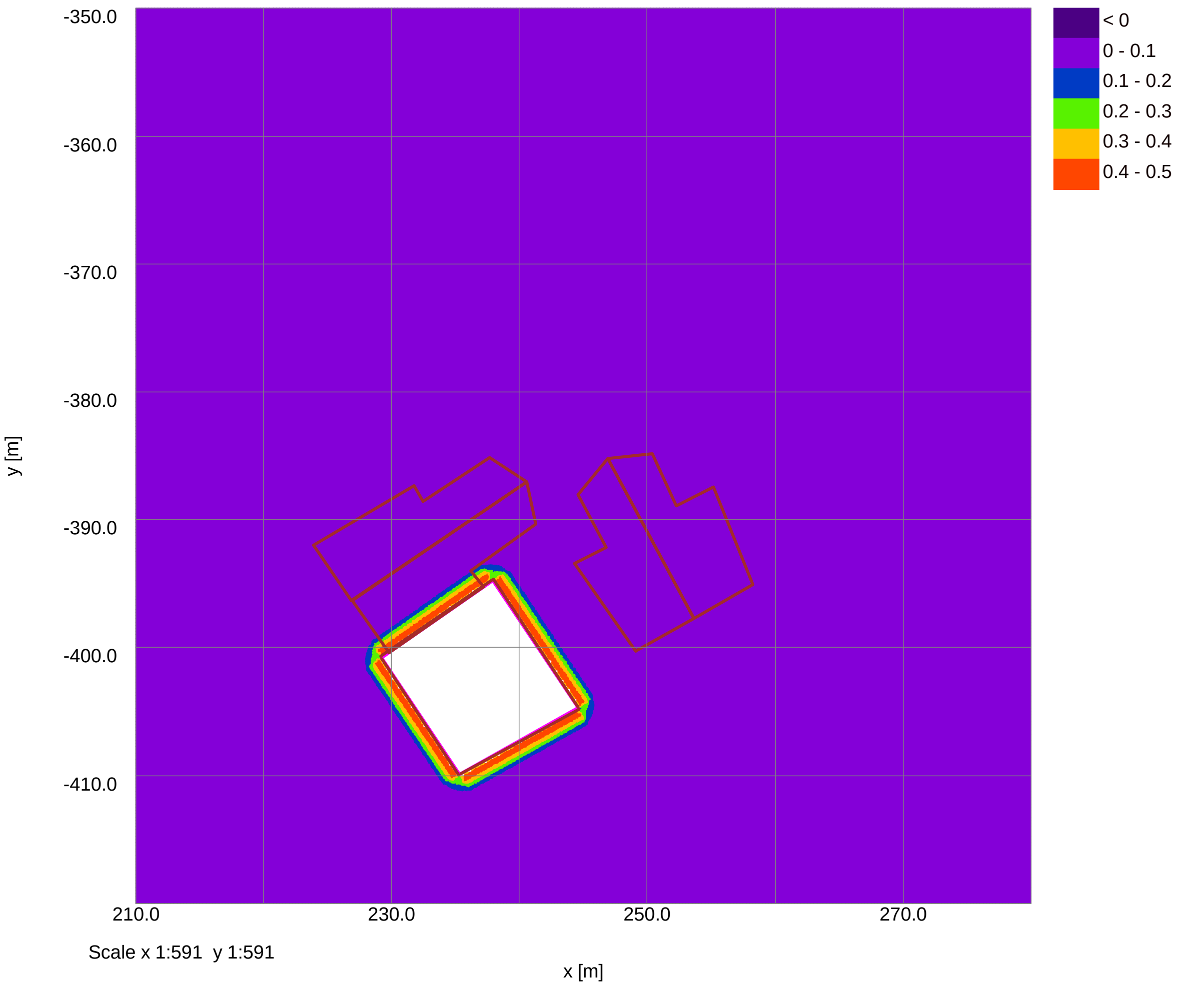
Short Term Movement

Total Movement

BUILDING DAMAGE ASSESSMENT (X-DISP)

Key Plan

Vertical Settlement Contours: Grid 2 (level -2.150m) (Interval 0.1mm)



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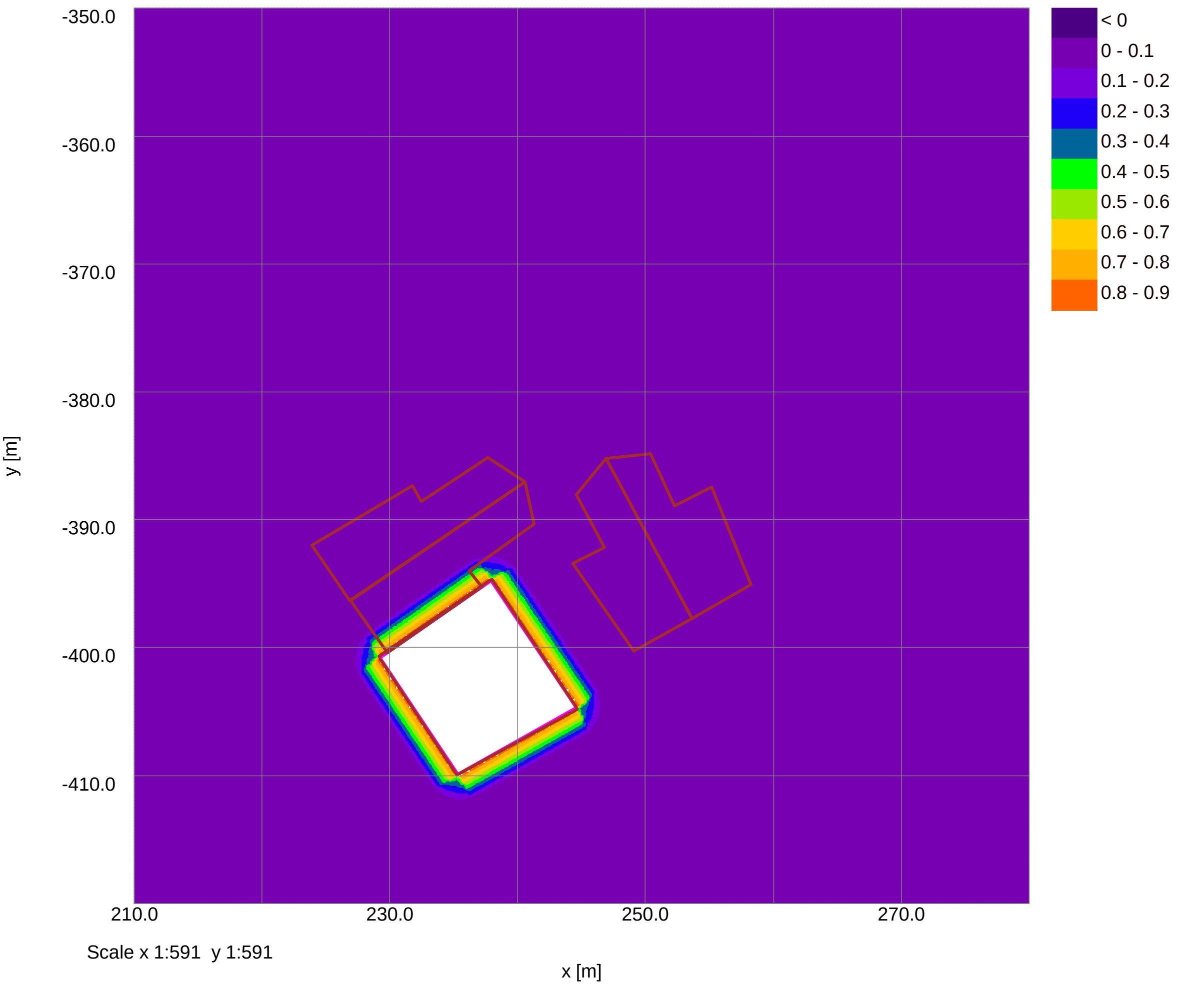
Horizontal Displacement Contours: Grid 2 (level -2.150m) Interval 0.1mm



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Oasys

Bull and Last PH
New Basement
Excavation

GEA LIMITED
(GEOTECHNICAL &ENV ASSOC)

Job No.	Sheet No.	Rev.
J15145		

Drg. Ref.		
Made by	Date	Checked
JD	17-Aug-2015