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Report on
Pillar Stability and Subsidence Modelling

Newcastle Art Gallery Proposed Alterations and Additions
1 Laman Street, Newcastle

Prepared for
Newcastle City Council

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Report on Pillar Stability and Subsidence Modelling
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1 Laman Street, Newcastle

1. Introduction

This report presents the results of numerical modelling of mine workings in the Borehole Seam to assess the grout remediation requirements for the proposed Newcastle Art Gallery Alterations and Additions at 1 Laman Street, Newcastle. The investigation was commissioned in an email dated 30 March, 2021 by Matthew Bennett of Newcastle City Council (NCC) and was undertaken with reference to Douglas Partners Pty Ltd (DP) email proposal NCL200485.P.003.Rev0.

The development will comprise the extension of the existing Art Gallery Building on the eastern side of the existing building, a basement is proposed along with a three-storey building above ground level (ie total four storeys).

The site lies within the proclaimed Mine Subsidence District of Newcastle and development on the site is subject to the approval of Subsidence Advisory NSW (SA NSW).

With reference to SA NSW (2018), Appendix C, Table 2, the proposed development is classified as building type category 'B3' as it is a public building, likely with high trafficability and due to the cost of the development.

This report presents the results of the numerical modelling of mine subsidence in the Borehole Seam workings and the requirements of grouting to reduce mine subsidence parameters.

This report does not consider mine workings in the upper Dudley / Yard Seam as it has been recommended that these workings are fully grouted as discussed in DP report (DP, 2020).

2. Previous Investigations

DP has previously undertaken investigations at the proposed site (DP, 2021) that included the drilling of two boreholes supplemented by down-hole CCTV and down-hole sonar. The aim of the previous investigations was to provide information on the condition of the workings beneath the site including, depth of cover to the coal seam, seam thickness, working height, the presence of rubble within the void, layout of the workings and bord width. In addition, the following was undertaken:

- Pillar stability analysis for pillars in the Borehole Seam beneath the site and within the angle of draw of the proposed development (based on available information);
- Comments on the pillar stability of the Borehole Seam Workings and the likelihood of mine subsidence affecting the site;

- Sensitivity analysis for the pillar stability (as required by SA NSW);
  - Pillar width as mapped on the RT;
  - Reduce pillar widths;
  - Increased pillar heights.
- Comments on the strains, tilts and curvatures which could occur from a hypothetical 'worst case' subsidence event;
- Recommendations for subsidence management such as structural design parameters or targeted grouting, as well as subsidence implications for the proposed development in line with SA NSW Development Application-Merit Policy.

Based on the pillar stability analysis in (DP, 2021) for the Borehole Seam, it was concluded that the pillar panel FoS do not satisfy (SA NSW, 2018)for a B3 category structure with a moderate uncertainty factor, also W:H ratios are less than SA NSW (2018) requirements. Furthermore, the assessed mine subsidence parameters presented in (DP, 2021) were considered too high by the project structural engineers to be accommodated in the design of the structure and therefore remedial grouting was recommended to reduce the mine subsidence design parameters to acceptable levels.

3. Scope of Work

The scope and aims of the current assessment are as follows:

- Review of available data including review of Record Trace (RT) (mine plans);
- Review of geological mapping;
- Review of relevant available geotechnical data including previous DP reports and in-house records;
- Based on previous pillar stability analysis and site investigation results (DP, 2021):
- Estimate the maximum predicted 'worst-case' subsidence parameters for design using 3D finite difference modelling (FDM) assuming grouting of the Borehole Seam mine workings is NOT undertaken;
- Estimate the maximum predicted 'worst-case' subsidence parameters for design using 3D finite difference modelling (FDM) assuming grouting of the Borehole Seam mine workings IS undertaken.
- Estimates of maximum subsidence, tilt, curvature, and horizontal strain profiles over the subject site pre and post grouting.

4. Site Description

The site is identified as Lots 11 to 14 (and Part Lot 15) DP 1122031, Lot 1 DP 63100, Lot 1 DP 516670 and Part Lot 18 Section G DP 9789, 1 Laman Street, Cooks Hill, New South Wales and is shown on Drawing 101, Appendix D. The site comprises and irregular shaped area of approximately 1830 m^2 which currently comprises car parking and landscaped areas which form part of the Newcastle Art Gallery.

The site is bounded by to the east by Darby Street, to the north by Laman Street, to the south by Queen Street and to the west by the existing art gallery building.

The ground surface at the site generally slopes down to the north - east (ie Laman Street) at about 2° to 5° and comprised sealed pavements and gardens with trees.

The site is shown in Figure 1 below.

Figure 1: Aerial image of site and surrounds. Red line denotes site boundary and the yellow dashed line denotes the existing art gallery buildings

5. Data Review

5.1 Regional Geology

Reference to the Newcastle Coalfields Surface Geology Sheet, published by BHP, indicates that the site is underlain by the Lambton sub-group rocks of the Newcastle Coal Measures. The rocks are of Permian age and typically comprise sandstone, siltstone, claystone and multiple coal seams. Further details regarding the site geology can be found in (DP, 2021).

5.2 RT566 and History of Mining

The site was undermined by workings in the Borehole Seam by the AA Co as part of the No. 2 Hamilton Pit workings. These workings were recorded within trace RT566, dated 7 June 1901. There are three versions of RT566. The three versions are dated 1860, 1877 and 1901. RT566 indicates the AA Co started bord and pillar style mining in the Borehole Seam prior to 1860 and completed mining by 1901.

RT566 indicates that the workings are present below the whole of the site and beyond. The RT indicates that the northern edge of the workings is below Hunter Street, approximately 300 m to the north of the site and extends a significant distance to the south, west as far as a barrier located near Union Street (600 m) and the north-east to about Market Street (800 m).

The workings are shown as bord and pillar, with pillar widths typically in the range 9 m to 12 m and bord widths of 5 m to 6.5 m. The pillars are generally shown as rectangular with lengths typically in the range 10 m to 70 m (more typically 10 m to 35 m). Width to height ratios are typically in the range 1.7 to 2.2.

The seam thickness shown on RT566 is typically about 6.2 m to 6.4 m (however a seam thickness of 6.8 m was encountered during previous investigation to the north) and mining of the seam was typically undertaken in three stages as follows, presented in stratigraphic order (To, 1988):

- Third Workings – 1.2 m;
- First Workings – 2.6 m; and
- Second Workings – 1.6 m.

Therefore, the total workings section ranged up to about 5.4 m, however in places only the first or first and second workings were undertaken in which case the working section would be 2.6 m or 4.2 m.

A seam section from RT566 is reproduced in Figure 2 below.

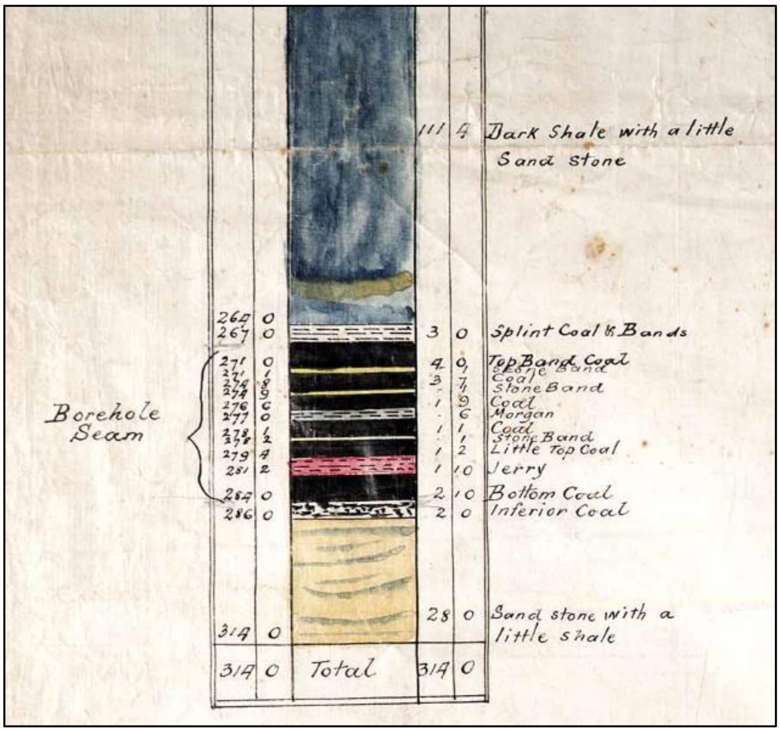

Figure 2: Seam section of Borehole Seam from RT566

Instability in the Borehole Seam mine workings in the Newcastle CBD area to the east of the site occurred in the early 1900s. The subsidence occurred as three occurrences, or 'creeps' (To, 1988) as follows:

- First Creep – this occurred on 15 May 1906 and covered an area to the south of Ordnance Street, below King Edward Park. Subsidence in the range 400 mm to 825 mm was reported with surface cracks of up to 75 mm width;
- Second Creep – this occurred on 17 October 1907 and extended from the area of the First Creep, north to Church Street, falling just to the south of the Cathedral and covering the area below James Fletcher Hospital and Newcastle Grammar School. Subsidence in the range 225 mm to 775 mm was observed, with about 25 mm occurring at the Cathedral; and
- Third Creep – this is reported to have occurred on 17 January 1908 and covered an area from Church Street, north to Scott Street and West to Perkins Street. Thrust from the hill and earth movement were noticeable and roads, pavements and buildings were damaged. There was no pronounced surface subsidence. Damage is reported to have occurred to the Cathedral, Central Methodist Mission, Burkes Store and the School of Arts.

5.3 Data from Royal Commission into Earth Subsidence at Newcastle

Data presented to the 1908 Royal Commission into Earth Subsidence at Newcastle (NSW Government, 1908) indicates that in the area of the first creep (The Hill and Newcastle CBD) the coal was worked in three stages. The initial workings were undertaken from the middle of the seam, with a working section of about 2.64 m, of which 2.29 m was coal and the remainder rock bands.

The floor was removed in the second workings which had a working section of about 1.6 m of which 0.97 m was coal and the remainder rock bands.

The third workings comprised removal of the top coal in retreat, with a working section of about 1.25 m which was entirely coal.

Hence the total working section in that area was about 5.46 m, of which about 4.5 m was coal, and remainder rock bands. The latter would normally be left in the mine.

At the top of the seam a 1.2 m thickness of splint coal and band was left in the roof, hence the total seam thickness in that area was about 6.68 m.

Referring to the AA Company (AA Co) workings, it has been reported that the coal left in place usually fell soon after the top coal was taken. Hence the effective pillar height at the time of the creeps would be equivalent to at least the full seam thickness.

Data presented to the Royal Commission on Earth Subsidence indicated that the maximum subsidence of the First creep in the Borehole Seam was 1' 4" to 2' 9" (i.e. about 405 mm to 840 mm) and the second creep 9" to 2ft 7" (i.e. about 230 mm to about 790 mm). A summary is presented in Table 1.

Table 1: Summary of Creep Events in Borehole Seam

Mine Workings	Cover Depth (m)	Mining Height h (m)	Extraction Ratio e (%)	Measured Subsidence Smax (m)	Smax/h*e
Creep 1 & 2	110 – 115	5.5	39	230 – 840	0.11 – 0.40

The observations from "creep" events has been used to calibrate the 3D finite difference modelling, in particular, the overburden and coal pillar strength and stiffness.

6. 3D Numerical Modelling

3D finite difference software (Flac^{3D}) was used for the numerical modelling and has been calibrated to the historical creep events outlined in Table 1. FLAC^{3D} (Fast Lagrangian Analysis of Continua) is a three-dimensional explicit finite difference program for modelling of soil, rock and structural behaviour. FLAC^{3D} is an analysis and design tool for geotechnical, civil and mining engineers that can be applied to a broad range of problems in engineering studies. Materials are represented by elements, or zones, which form a grid that is adjusted by the user to fit the shape of the object to be modelled. Each element behaves according to a prescribed linear or non-linear stress/strain law in response to the applied forces or boundary restraints.

FLAC^{3D} is ideally suited for modelling geomechanically problems that consist of several stages, such as sequential excavation, loading and de-stressing. The explicit Lagrangian calculation scheme and the mixed-discretization zoning technique used in FLAC^{3D} ensure that plastic collapse and flow are modelled accurately. The material can yield and flow and the grid can deform (in large-strain mode) and move with the material that is represented. The formulation can accommodate large displacements and strains and non-linear material behaviour, even if yield or failure occurs over a large area or if total collapse occurs (ie pillar collapse).

The aim of the numerical modelling is threefold; firstly, to more accurately determine the pillar loads for the Borehole seam workings at the site and assess the accuracy the tributary area theory adopted previously (DP, 2021); secondly to provide a means to identify areas where pillars are at increased risk of collapse more widely in the vicinity of the site and to evaluate the possibility of pillar run scenarios, and; thirdly to estimate past and future potential subsidence. Although it is possible to assess the effects of load shedding and risk of pillar runs using empirical techniques, the results are often approximate and numerical modelling is capable of providing a more rigorous assessment of these aspects.

Based on the RT and review of existing data, the parameters used for the pillar stability assessment are summarised as follows:

- Indicative depth of cover was inferred to be approximately 74 m depth;
- A working section of 5.4 m.

The analysis was carried out for the bulk weight of the overburden, i.e. the weight of the rock strata and groundwater contained within, with no account for internal water pressure effects within the flooded workings.

3D numerical finite difference modelling was undertaken to assist in establishing the following:

- Pillar stresses;
- Pillar stress 'hot-spots' which could indicate a likely area of pillar run and/or collapse; and
- Subsidence.

The accuracy of any numerical software depends entirely on the accuracy of the input parameters. Therefore, it is preferred that the input parameters are calibrated with the best available information, either; measured, observed, or empirically derived from past knowledge.

When constructing a model in 3D, the geometry of the mining in the seams and the topography are known and can be digitised into the software. The most critical input parameters with regard to accurately calculating stresses are;

- Overburden Depth;
- Rock Mass Stiffness;
- Crushed Pillar/Goaf Stiffness;
- Coal Strength.

In the case of the proposed site, the 3D finite difference input parameters have been carefully chosen based on previous creep events, empiricism, geotechnical information, and past assessments of the Borehole Seam mine workings.

6.1 3D Model details

Specific details of the Flac^{3D} model are as follows:

- Model size approximately 1 km x 1 km square (Drawing 1);
- General Model Geometry and mesh/grid size (Drawing 3 and Drawing 4);
- Mine workings as per RT566 and positioned as shown (Drawing 1, Drawing 2 and Drawing 4);
- Surface topology (RL(m) AHD) included (Drawing 1) in 3D Model;
- Nonlinear constitutive model for overburden;
- Previously grouted sites not included in current modelling;
- Workings in the upper 'Yard' / Dudley Seam do not contribute to the subsidence at the site;
- Nonlinear elasto-plastic constitutive model for coal pillars. Softened/residual pillar stiffness of 36MPa.

6.2 Results of Numerical Analysis of Pillars

Predicted pillar vertical stresses from the numerical modelling are shown in Figure 3 below and were found to be generally consistent with the values using tributary area theory. Higher stresses are evident on smaller pillars and in areas where the overburden depth increases (ie The Hill to the east of the site) which is to be expected.

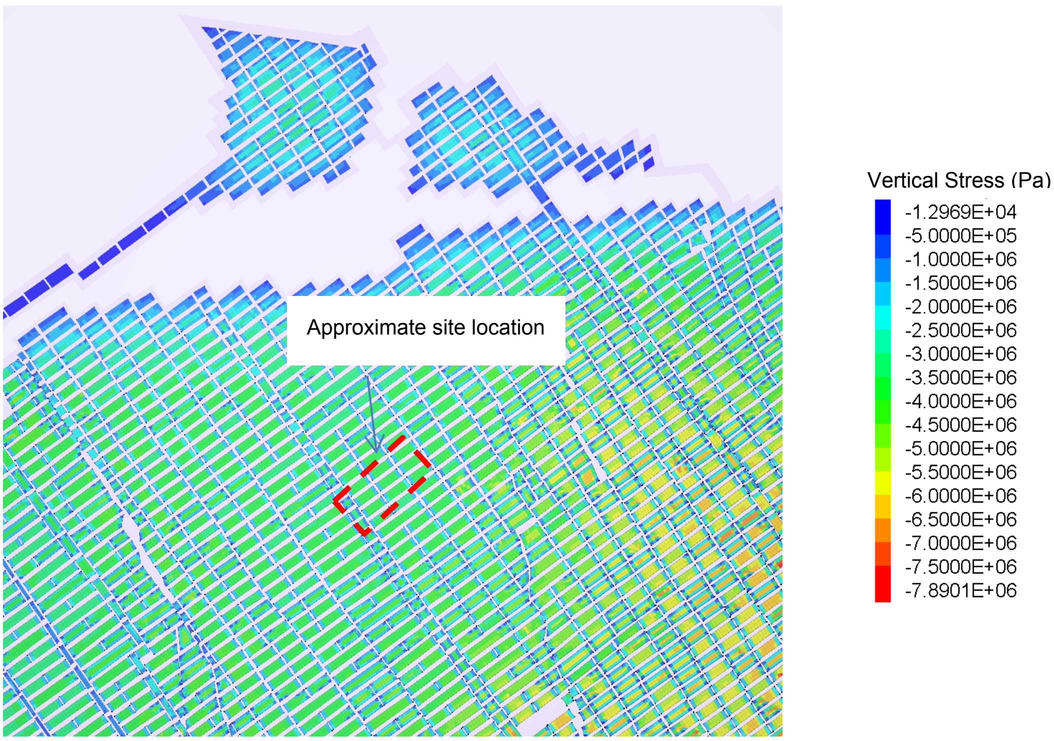

Figure 3 - 3D numerical modelling – Contours of vertical stress on pillars surrounding 1 Laman Street site

7. Subsidence Prediction

SA NSW (2018) describes an ‘absolute worst case’ subsidence event where all pillars with a width to height ratio of less than eight are assumed to fail. The pillar stability analysis in (DP, 2021) indicates that all the pillars within the panel have a width to height ratio of less than eight and therefore ‘absolute worst case’ subsidence parameters need to be estimated.

With regards to assessing past and future subsidence at this site, the following has been undertaken in the current assessment;

- Subsidence predictions (first pass) based on Holla (Holla, 1987)assuming all the bord and pillar workings for the site and surrounding area more generally have crushed;
- Subsidence predictions based on DP’s in-house method assuming all the bord and pillar workings for the site and surrounding area more generally have crushed;
- 3D finite difference modelling of the area with calibrated overburden and pillar stiffness assuming all the bord and pillar workings for the site and surrounding area more generally have crushed. The calibration has compared the measured subsidence from past creep events (Table 1);
- Prediction of worst case residual potential subsidence, tilts, strains and curvatures based on the finite difference modelling. This is referred to as the worst-case scenario.

7.1 First Pass Assessment of Supercritical Subsidence due to pillar crushing

Estimates of potential trough subsidence from pillar failure over a large area have been based on the analysis methods of Holla (Holla, 1987) and to adjust the working section height to allow for the unmined coal in the pillars in accordance with (Hawkins & Ramage, 2004):

- Historical working section (h) of 5.1 m to 6.5 m;
- Extraction ratio (e) of 0.43;
- Supercritical Panel; and
- Depth of cover of 74 m.

The results indicate the following:

- Maximum subsidence: 1.23 m – 1.57 m;
- Maximum tensile strain: 7 - 9 mm/m;
- Maximum compressive strain: 10 - 13 mm/m;
- Maximum tilt: 30 – 38 mm/m.

The above parameters are expected to provide an overly conservative estimate of the actual subsidence.

7.2 Worst-Case Subsidence parameters for Current Site – No Grouting

One commonly used approach to calculating the "worst case maximum subsidence" for failure of bord and pillar workings is to use the method of Holla (Holla, 1987) and Hawkins and Ramage (2004) as has been done in Section 7.1. However, data presented to the Royal Commission on Earth Subsidence indicated that the maximum subsidence of the first creep was 1ft 4" to 2ft 9" (i.e. about 405 mm to 840 mm) and the second creep 9" to 2ft 7" (i.e. about 230 mm to 790 mm). Hence, it follows that the method of Hawkins and Ramage (2004) used in Section 7.1 overestimates the likely worst-case subsidence for bord and pillar workings of the AA Co. The method of calculating maximum subsidence developed by Holla was based on subsidence data from longwall panels around 150 m wide and hence the failure mechanism is different to the mechanism which applied to Holla's (Holla, 1987) data.

An alternative approach is to calculate an apparent residual modulus of the crushed pillars at the site based on the first and second creeps (Table 1) and use this modulus to extrapolate the worst-case subsidence for large areas of pillars. This has been used previously for mine subsidence assessments (Douglas Partners Pty Ltd, 2015) and (DP, 2003).

For the maximum subsidence observed at the first creep and the overburden depth of 74 m, the apparent residual modulus is 36 MPa, which is similar to that observed for medium dense sands. Using this modulus, together with a working seam thickness of 5.4 m and overburden depth of 74 m, the worst-case ***supercritical subsidence*** for pillars under the site, if subject to full tributary loading, would be in the range of about 450 mm to 550 mm. This was estimated by using an in-house DP method which considers pillar load and geometry and a residual pillar modulus back-figured from subsidence observations and records associated with the first creep event.

The above subsidence estimates have been further refined with 3D finite difference modelling using the apparent residual modulus (adopted as 36MPa) combined with the pillar layout from the RT566. The predicted subsidence assuming crushing of all pillars in the vicinity of the site is shown Drawing 6 and Drawing 6b attached. These predictions are consistent with approximate range of 350 mm to 550 mm previously estimated using DP's in-house method.

With reference to Figure 6, the estimated point of inflexion of the subsidence trough along the solid coal barrier to the north was reviewed and is considered reasonable and also consistent with Holla (Holla, 1987). In addition, the predicted subsidence in the areas of the first and second creep events are consistent with the observations (Table 1) indicating successful model calibration of the overburden and coal material properties.

The predicted tilts and curvatures from the 3D finite difference modelling are presented in Drawing 7 and Drawing 8. The tilts and curvatures along the northern solid coal barrier are considered reasonable and also consistent with those previously reported by others.

After a full crush event for all pillars beneath the site, the residual tilts and curvatures are expected to be small. However, it should be remembered that subsidence, and the associated tilts and curvatures, are developed dynamically as the crush event/pillar run passes through the site. Consequently, the dynamic tilts and curvatures for the Art Gallery site could be as high the maximum values shown in Figures 7 and 8 due to a pillar run.

7.3 Worst-Case Subsidence parameters for Current Site – With Grouting

As reported in (DP, 2021), it is considered that the pillar panel FoS do not satisfy SA NSW (2018) for a B3 category structure with a moderate uncertainty factor, also pillar W:H ratios are less than SA NSW (2018) requirements. Therefore, with reference to SA NSW (2018), the structure is required to be designed to be *"safe, serviceable and any damage shall be limited to "very slight" in accordance with AS2870 (damage classification), and readily repairable",* for the subsidence parameters presented in (DP, 2021) and in Section 7.2 of this report, alternatively selective grouting be undertaken to improve subsidence parameters at the site.

3D finite difference modelling was undertaken assuming grout is placed strategically beneath the site. The grout locations adopted are as shown in Drawing 9.

The following assumptions have been made in the finite difference modelling:

- Grout UCS strength is 5 MPa;
- Grout stiffness/modulus in 850 MPa;
- Grout extends full height of void (to roof);

The results of the analysis are presented in Figures 10 to 14.

After placement of the grout, the maximum subsidence predicted in the event of a widespread pillar run is predicted to be less than 100 mm (Figure 11b), being generally less than 50 mm over much of the site for the proposed Gallery Additions. A summary of the worst-case subsidence parameters is provided in Table 2.

Table 2: Subsidence Parameters from 3d Modelling – Grout Included

	Worst Case Subsidence Parameters
Working Section (m) for Subsidence	5.4
Depth (m)	74
Maximum Surface Subsidence (mm)	50
Maximum Tilt (mm/m)	3
Radius of Curvature (1/km)	0.2
Horizontal Strain* (mm/m)	1.8

*Horizontal strain = 10 x curvature (1/km) based on published back analysis of subsidence data measurements above underground longwall and pillar extraction panel mines in the Newcastle Coalfield.

The structural design of the building will be required to accommodate the parameters presented in Table 3 such that the building will *be "safe, serviceable and any damage shall be limited to "very slight" in accordance with AS2870 (damage classification), and readily repairable"* in the unlikely event of a pillar crush.

8. Conclusion

The results of this assessment are summarised below along with recommendations to mitigate mine subsidence risk:

- Design of the proposed structure is required to comply with the requirements of SA NSW;
- Based on the predicted subsidence contours from 3D modelling, it is assessed that the grouting location option presented will limit maximum subsidence to < 100 mm and tilt to < 5 mm/m, with curvatures < 0.25 km and strains < 2.5 mm/m for 5 MPa grout;
- The recommended worst case design parameters for this site are given in Table 3 below.

Table 3: Worst Case Subsidence Parameters recommended for Design

Parameter	Recommended Design Value
Subsidence	≤ 50 mm
Tilt	≤ 3 mm/m
Minimum Radius of Curvature	≤ 0.2 (1/km)
Horizontal Strain	≤ 1.8 mm/m

- The worst-case design parameters should be adopted by the structural engineer during design of the proposed alterations and additions; and
- A grout methodology and verification plan will be required to be prepared and approved by SA NSW prior to the grouting works. In addition, site validation of the grouting works must be undertaken, and a validation report prepare and submitted to SA NSW at the completion of the grouting works to confirm that the grouting was undertaken in accordance with the methodology plan.

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10. Limitations

Douglas Partners Pty Ltd (DP) has prepared this report for this project at 1 Laman Street, Newcastle in accordance with DP's proposal NCL200485.P.003.Rev0 dated 29 March 2021 and acceptance received from Matthew Bennett from Newcastle City Council via email on 30 March 2021. The work was carried out under DP's Conditions of Engagement. This report is provided for the exclusive use of Newcastle City Council for this project only and for the purposes as described in the report. It should not be used by or relied upon for other projects or purposes on the same or other site or by a third party. Any party so relying upon this report beyond its exclusive use and purpose as stated above, and without the express written consent of DP, does so entirely at its own risk and without recourse to DP for any loss or damage. In preparing this report DP has necessarily relied upon information provided by the client and/or their agents.

This report must be read in conjunction with all of the attached and should be kept in its entirety without separation of individual pages or sections. DP cannot be held responsible for interpretations or conclusions made by others unless they are supported by an expressed statement, interpretation, outcome or conclusion stated in this report.

This report, or sections from this report, should not be used as part of a specification for a project, without review and agreement by DP. This is because this report has been written as advice and opinion rather than instructions for construction.

The contents of this report do not constitute formal design components such as are required, by the Health and Safety Legislation and Regulations, to be included in a Safety Report specifying the hazards likely to be encountered during construction and the controls required to mitigate risk. This design process requires risk assessment to be undertaken, with such assessment being dependent upon factors relating to likelihood of occurrence and consequences of damage to property and to life.
This, in turn, requires project data and analysis presently beyond the knowledge and project role respectively of DP. DP may be able, however, to assist the client in carrying out a risk assessment of potential hazards contained in the Comments section of this report, as an extension to the current scope of works, if so requested, and provided that suitable additional information is made available to DP. Any such risk assessment would, however, be necessarily restricted to the geotechnical components set out in this report and to their application by the project designers to project design, construction, maintenance and demolition.

Douglas Partners Pty Ltd

Appendix A

About This Report

About this Report

Douglas Partners

Introduction

These notes have been provided to amplify DP's report in regard to classification methods, field procedures and the comments section. Not all are necessarily relevant to all reports.

DP's reports are based on information gained from limited subsurface excavations and sampling, supplemented by knowledge of local geology and experience. For this reason, they must be regarded as interpretive rather than factual documents, limited to some extent by the scope of information on which they rely.

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Borehole and Test Pit Logs

The borehole and test pit logs presented in this report are an engineering and/or geological interpretation of the subsurface conditions, and their reliability will depend to some extent on frequency of sampling and the method of drilling or excavation. Ideally, continuous undisturbed sampling or core drilling will provide the most reliable assessment, but this is not always practicable or possible to justify on economic grounds. In any case the boreholes and test pits represent only a very small sample of the total subsurface profile.

Interpretation of the information and its application to design and construction should therefore take into account the spacing of boreholes or pits, the frequency of sampling, and the possibility of other than 'straight line' variations between the test locations.

Groundwater

Where groundwater levels are measured in boreholes there are several potential problems, namely:

- In low permeability soils groundwater may enter the hole very slowly or perhaps not at all during the time the hole is left open;
- A localised, perched water table may lead to an erroneous indication of the true water table;
- Water table levels will vary from time to time with seasons or recent weather changes. They may not be the same at the time of construction as are indicated in the report; and
- The use of water or mud as a drilling fluid will mask any groundwater inflow. Water has to be blown out of the hole and drilling mud must first be washed out of the hole if water measurements are to be made.

More reliable measurements can be made by installing standpipes which are read at intervals over several days, or perhaps weeks for low permeability soils. Piezometers, sealed in a particular stratum, may be advisable in low permeability soils or where there may be interference from a perched water table.

Reports

The report has been prepared by qualified personnel, is based on the information obtained from field and laboratory testing, and has been undertaken to current engineering standards of interpretation and analysis. Where the report has been prepared for a specific design proposal, the information and interpretation may not be relevant if the design proposal is changed. If this happens, DP will be pleased to review the report and the sufficiency of the investigation work.

Every care is taken with the report as it relates to interpretation of subsurface conditions, discussion of geotechnical and environmental aspects, and recommendations or suggestions for design and construction. However, DP cannot always anticipate or assume responsibility for:

- Unexpected variations in ground conditions. The potential for this will depend partly on borehole or pit spacing and sampling frequency;
- Changes in policy or interpretations of policy by statutory authorities; or
- The actions of contractors responding to commercial pressures.

If these occur, DP will be pleased to assist with investigations or advice to resolve the matter.

About this Report

Site Anomalies

In the event that conditions encountered on site during construction appear to vary from those which were expected from the information contained in the report, DP requests that it be immediately notified. Most problems are much more readily resolved when conditions are exposed rather than at some later stage, well after the event.

Information for Contractual Purposes

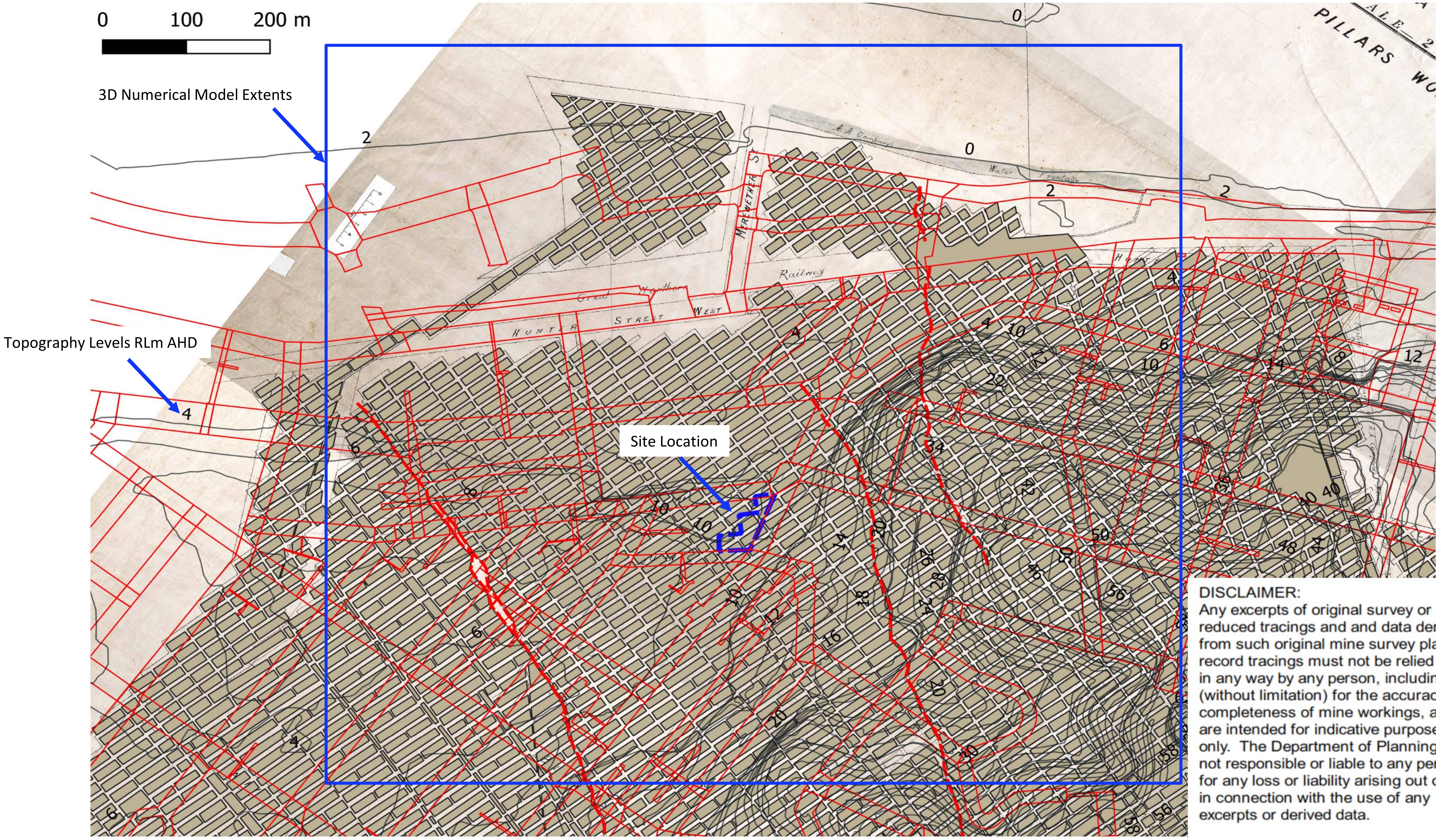
Where information obtained from this report is provided for tendering purposes, it is recommended that all information, including the written report and discussion, be made available. In circumstances where the discussion or comments section is not relevant to the contractual situation, it may be appropriate to prepare a specially edited document. DP would be pleased to assist in this regard and/or to make additional report copies available for contract purposes at a nominal charge.

Site Inspection

The company will always be pleased to provide engineering inspection services for geotechnical and environmental aspects of work to which this report is related. This could range from a site visit to confirm that conditions exposed are as expected, to full time engineering presence on site.

Appendix B

Borehole Seam Mine workings and approximate site location



DISCLAIMER:
Any excerpts of original survey or reduced tracings and and data derived from such original mine survey plans or record tracings must not be relied upon in any way by any person, including (without limitation) for the accuracy or completeness of mine workings, and are intended for indicative purposes only. The Department of Planning is not responsible or liable to any person for any loss or liability arising out of or in connection with the use of any excerpts or derived data.

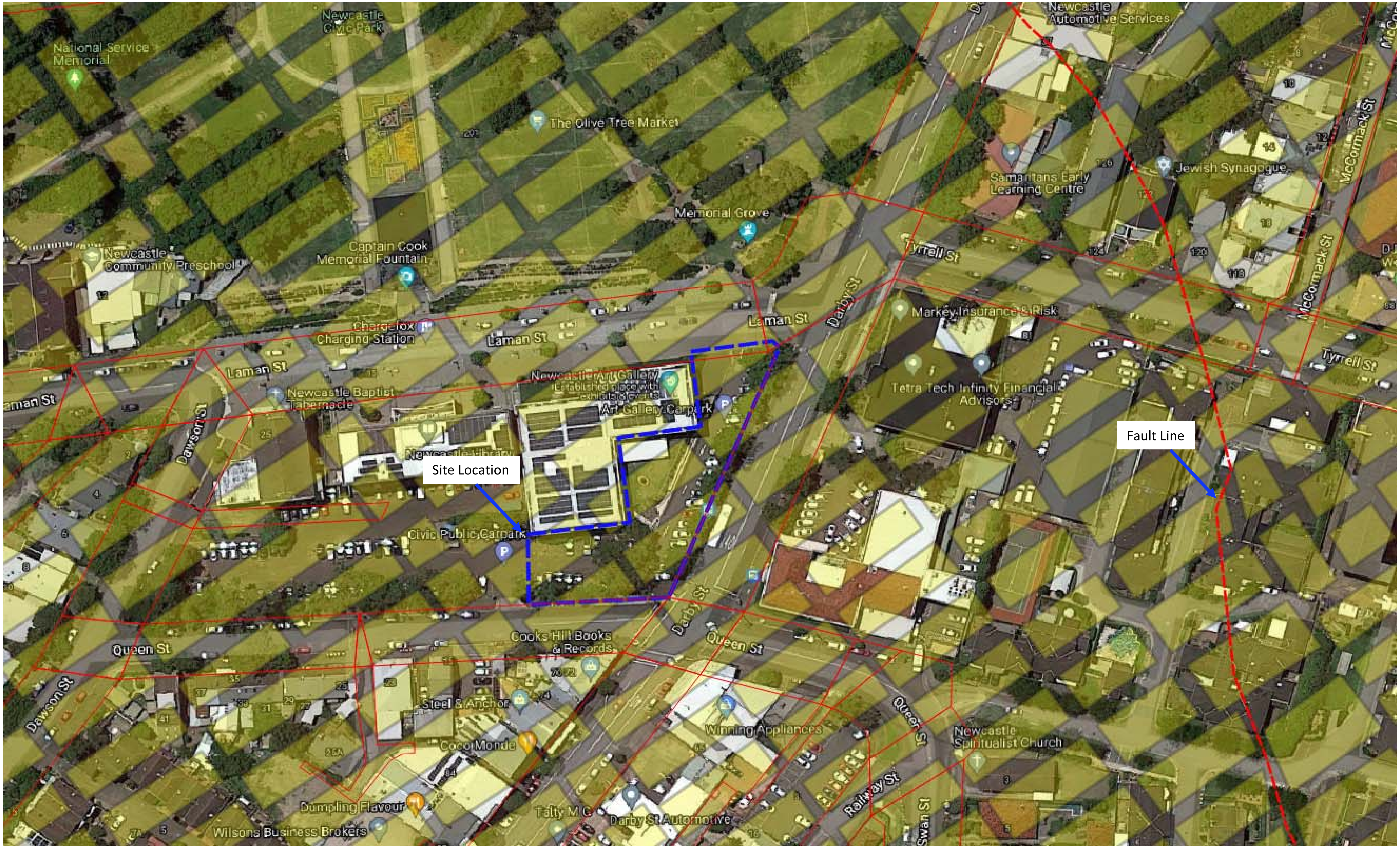
Douglas Partners
Geotechnics / Environment / Groundwater

CLIENT:	Newcastle City Council		
OFFICE:	Newcastle	SCALE	As Shown
DATE:	17 Jun 2021	DRAWN BY:	RSM

TITLE: **Approximate layout of Borehole Seam Workings (RT566) and site location**
Newcastle Art Gallery - Proposed Alterations and Additions
1 Laman Street, Newcastle

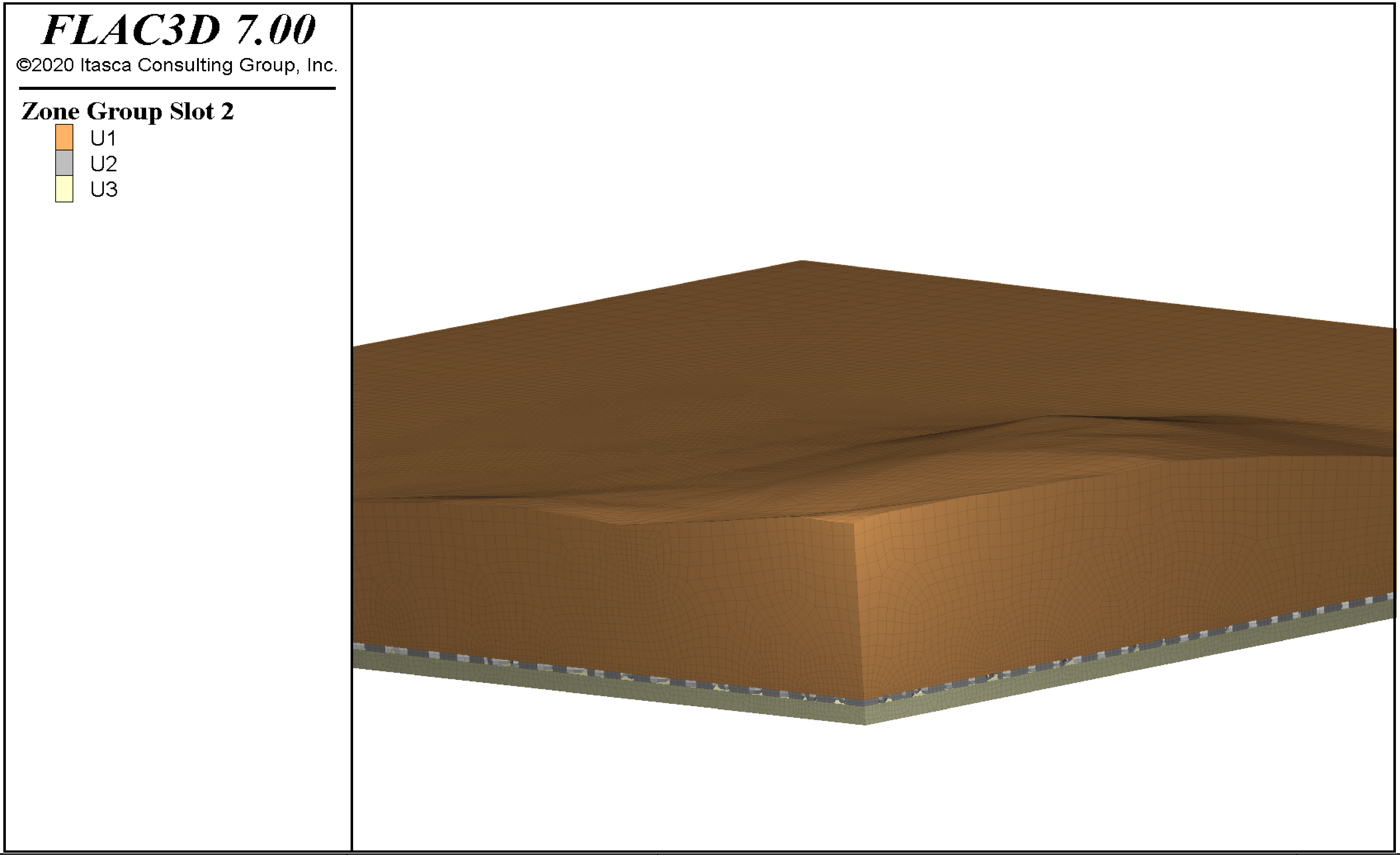
PROJECT No:	49737.05
DRAWING No:	1
REVISION:	1

Borehole Seam Mine workings and approximate site location



	CLIENT: Newcastle City Council		TITLE:	Borehole Seam Workings (RT566) and approx site location	PROJECT No:	49737.05
Douglas Partners Geotechnics / Environment / Groundwater	OFFICE: Newcastle	SCALE NTS		Newcastle Art Gallery - Proposed Alterations and Additions	DRAWING No:	2
	DATE: 17 Jun 2021	DRAWN BY: RSM		1 Laman Street, Newcastle	REVISION:	1

Flac3D Model



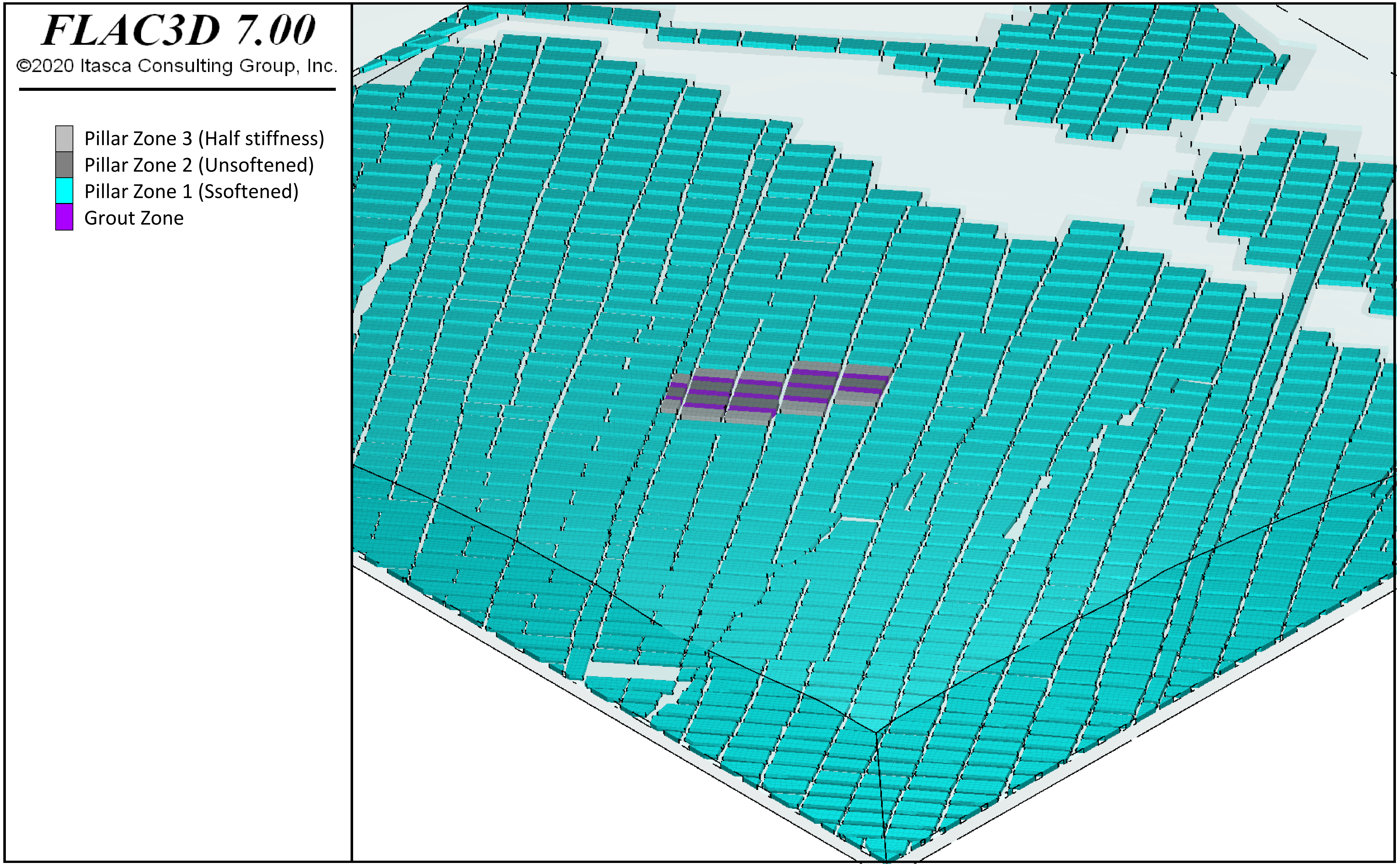
Douglas Partners
Geotechnics / Environment / Groundwater

CLIENT:	Newcastle City Council		
OFFICE:	Newcastle	SCALE	NTS
DATE:	17 Jun 2021	DRAWN BY:	RSM

TITLE: **Flac3D Model geometry incl overburden topography**
Newcastle Art Gallery - Proposed Alterations and Additions
1 Laman Street, Newcastle

PROJECT No:	49737.05
DRAWING No:	3
REVISION:	1

Flac3D Model



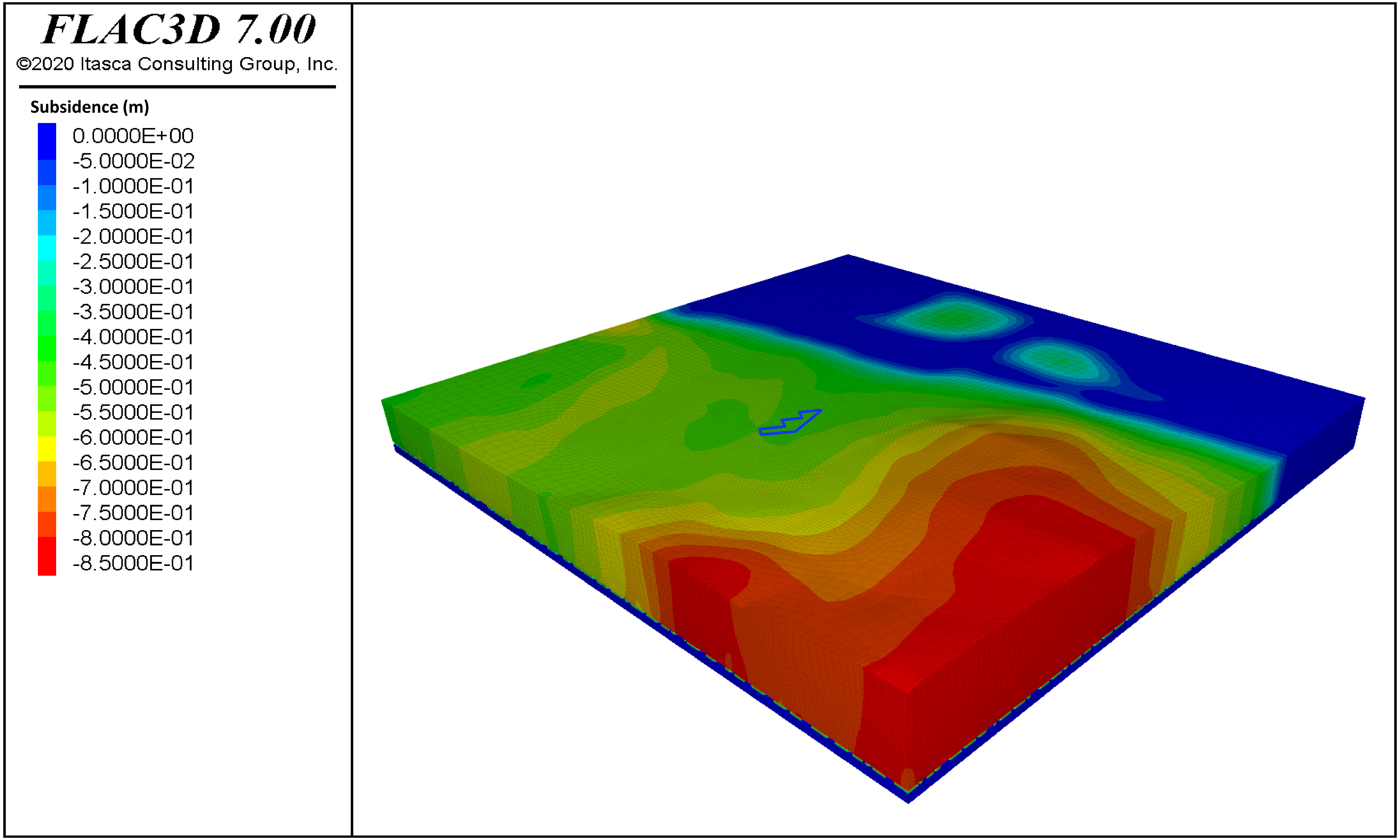
Douglas Partners
Geotechnics / Environment / Groundwater

CLIENT:	Newcastle City Council		
OFFICE:	Newcastle	SCALE	NTS
DATE:	26 Jul 2021	DRAWN BY:	RSM

TITLE: **Flac3D Model geometry incl overburden topography**
Newcastle Art Gallery - Proposed Alterations and Additions
1 Laman Street, Newcastle

PROJECT No:	49737.05
DRAWING No:	4
REVISION:	2

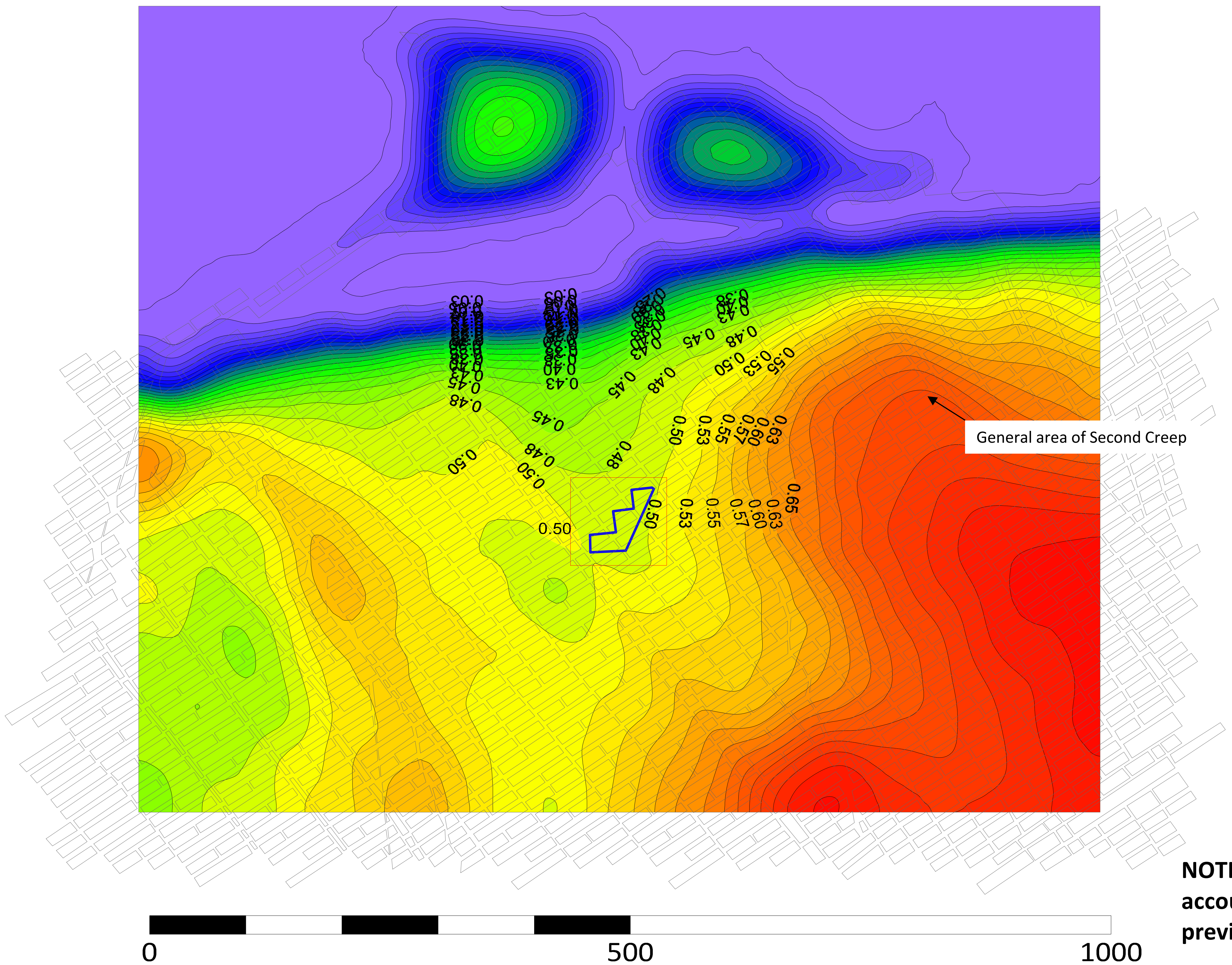
Vertical Subsidence of ungrouted workings (m)

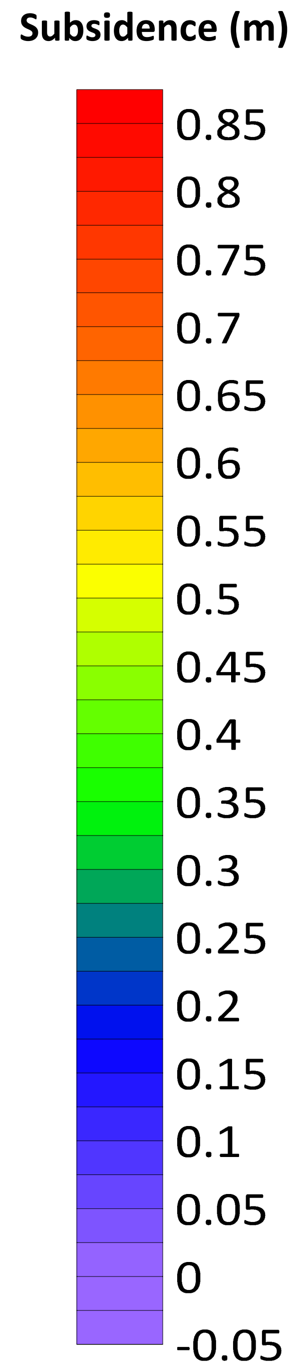


Douglas Partners
Geotechnics / Environment / Groundwater

CLIENT:	Newcastle City Council			TITLE:	**Vertical Subsidence of ungrouted workings (m)**	PROJECT No: 49737.05
OFFICE:	Newcastle	SCALE	NTS		**Newcastle Art Gallery - Proposed Alterations and Additions**	DRAWING No: 5
DATE:	26 Jul 2021	DRAWN BY:	RSM		**1 Laman Street, Newcastle**	REVISION: 2

Predicted Vertical Subsidence with no Grout (m)





NOTE: Subsidence predictions do not account for beneficial effects from previously grouted CBD sites

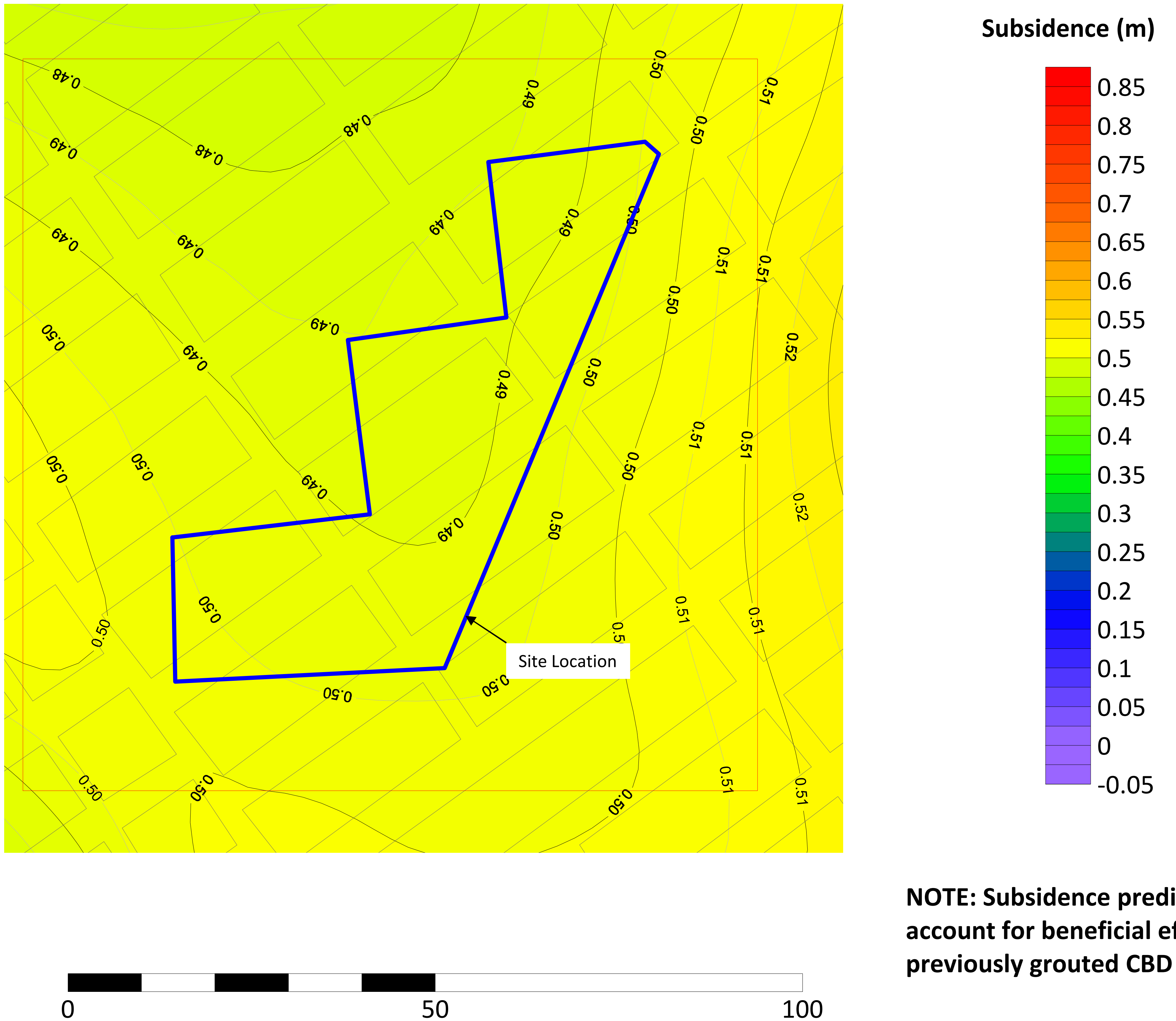
Douglas Partners
Geotechnics / Environment / Groundwater

CLIENT:	Newcastle City Council		
OFFICE:	Newcastle	SCALE	As Shown
DATE:	17 Jun 2021	DRAWN BY:	RSM

TITLE: **Predicted Vertical Subsidence with no Grout (m)**
Newcastle Art Gallery - Proposed Alterations and Additions
1 Laman Street, Newcastle

PROJECT No:	49737.05
DRAWING No:	6
REVISION:	1

Predicted Vertical Subsidence with no Grout (m)



NOTE: Subsidence predictions do no account for beneficial effects from previously grouted CBD sites

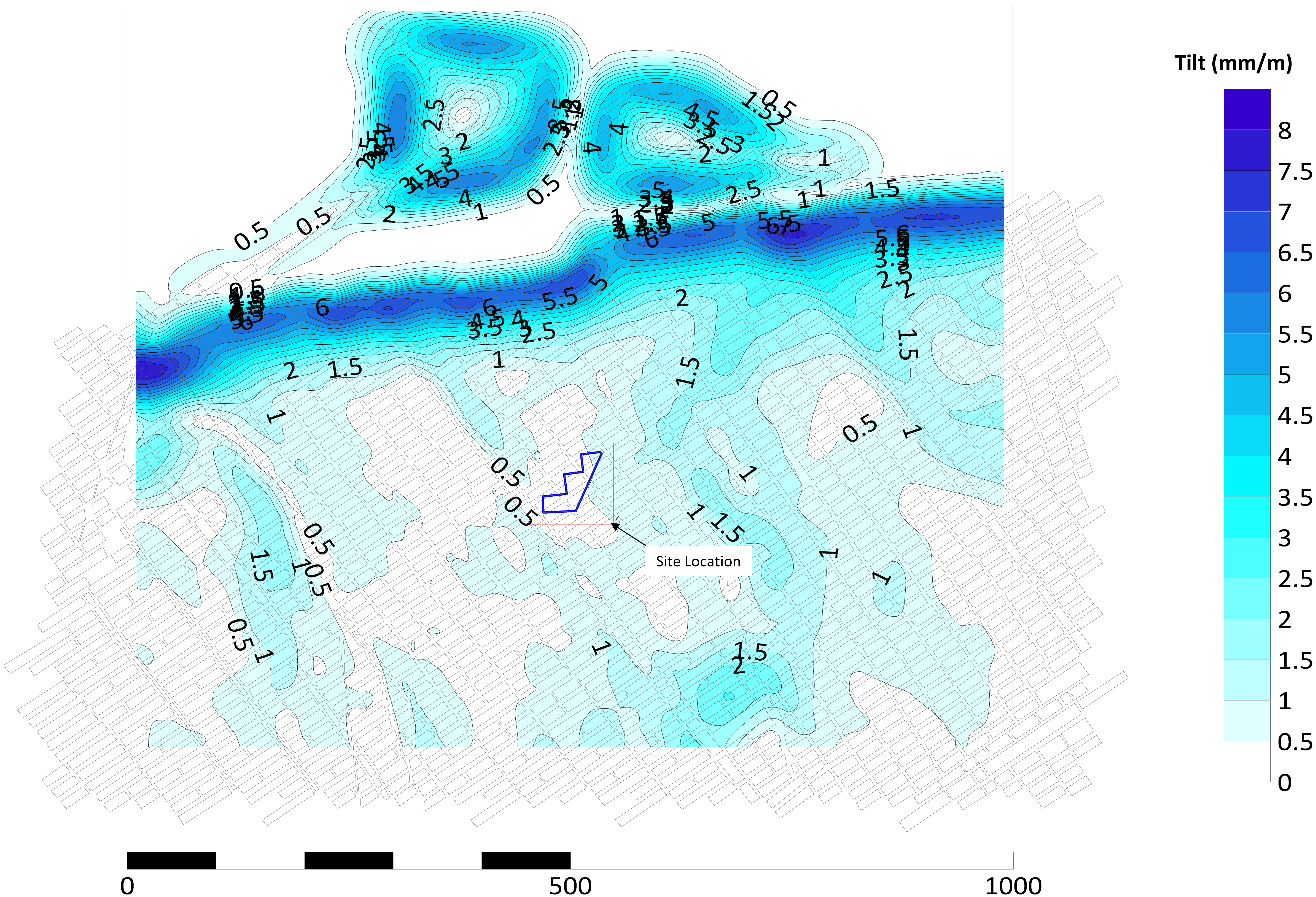
Douglas Partners
Geotechnics / Environment / Groundwater

CLIENT:	Newcastle City Council		
OFFICE:	Newcastle	SCALE	As Shown
DATE:	17 Jun 2021	DRAWN BY:	RSM

TITLE: **Predicted Vertical Subsidence with no Grout (m)**
Newcastle Art Gallery - Proposed Alterations and Additions
1 Laman Street, Newcastle

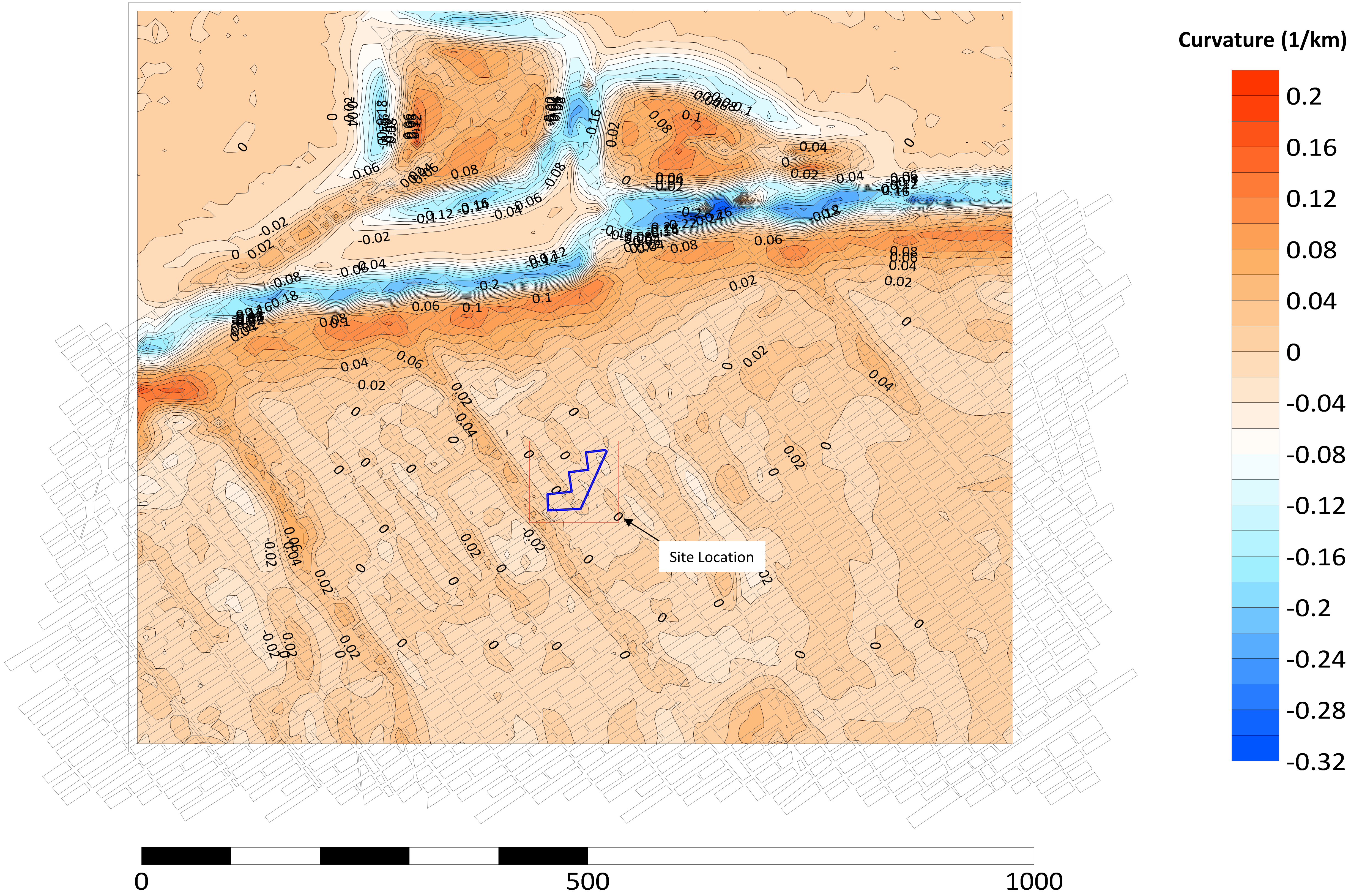
PROJECT No:	49737.05
DRAWING No:	6b
REVISION:	1

Predicted Tilt with no Grout (mm/m)



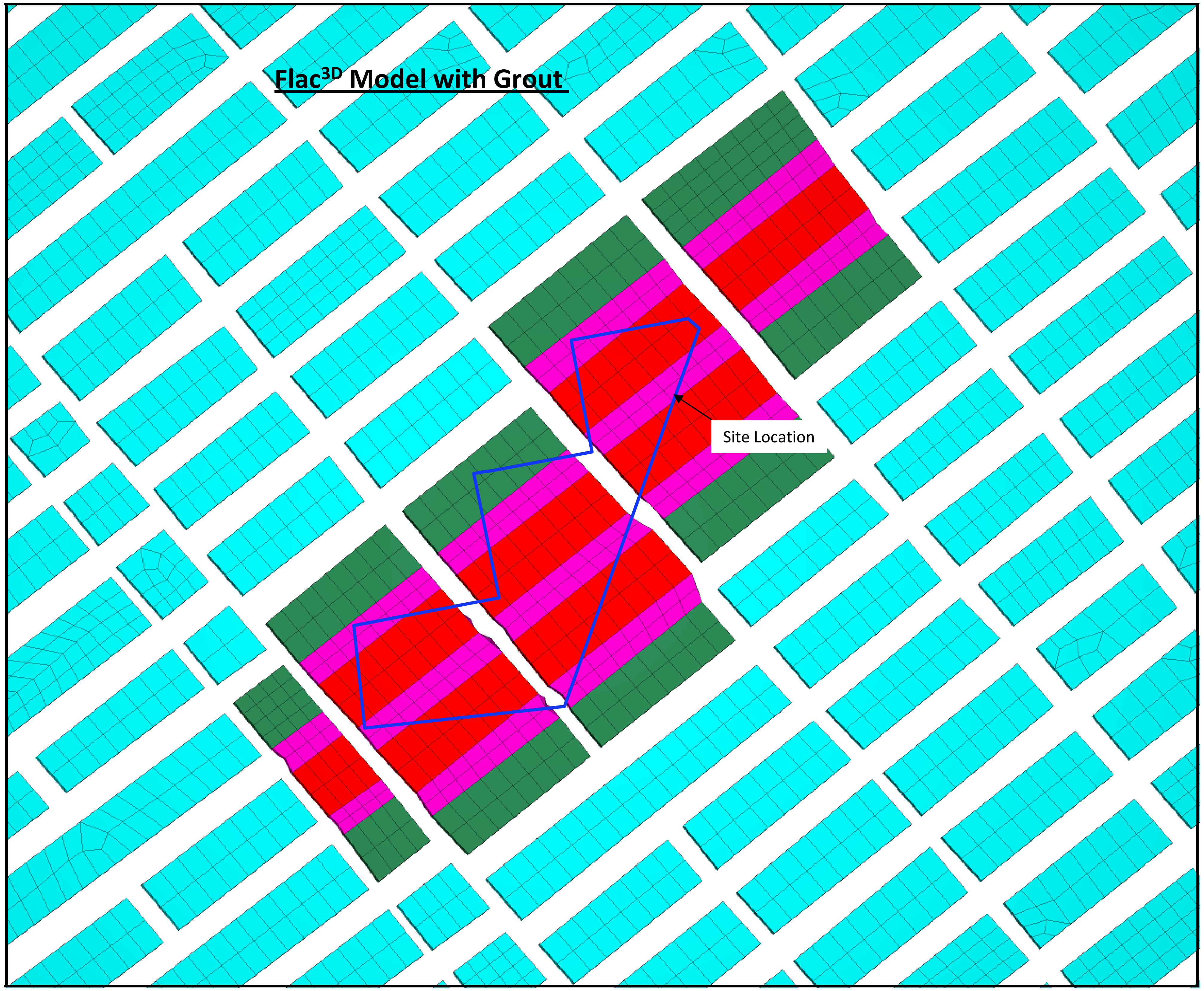
Douglas Partners Geotechnics / Environment / Groundwater	CLIENT: Newcastle City Council		TITLE:	Predicted Tilt with no Grout (mm/m)	PROJECT No:	49737.05
	OFFICE: Newcastle	SCALE As Shown		Newcastle Art Gallery - Proposed Alterations and Additions	DRAWING No:	7
	DATE: 17 Jun 2021	DRAWN BY: RSM		1 Laman Street, Newcastle	REVISION:	1

Predicted Curvature with no Grout (1/km)

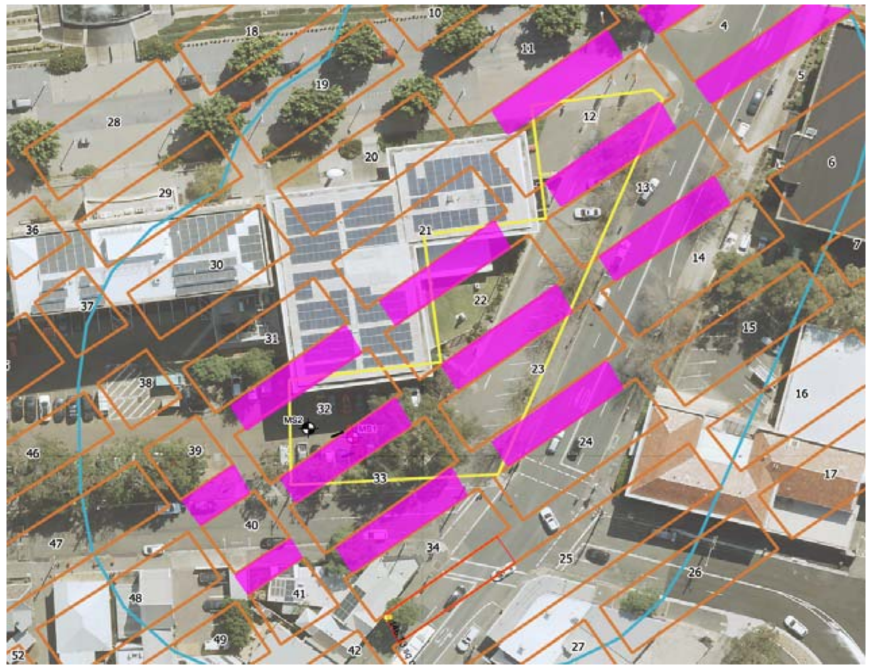


Douglas Partners Geotechnics / Environment / Groundwater						
CLIENT: Newcastle City Council			TITLE:	**Predicted Curvature with no Grout (1/km)**	PROJECT No:	49737.05
OFFICE: Newcastle	SCALE	As Shown		**Newcastle Art Gallery - Proposed Alterations and Additions**	DRAWING No:	8
DATE: 17 Jun 2021	DRAWN BY:	RSM		**1 Laman Street, Newcastle**	REVISION:	1

Grout Locations and Affected Pillars

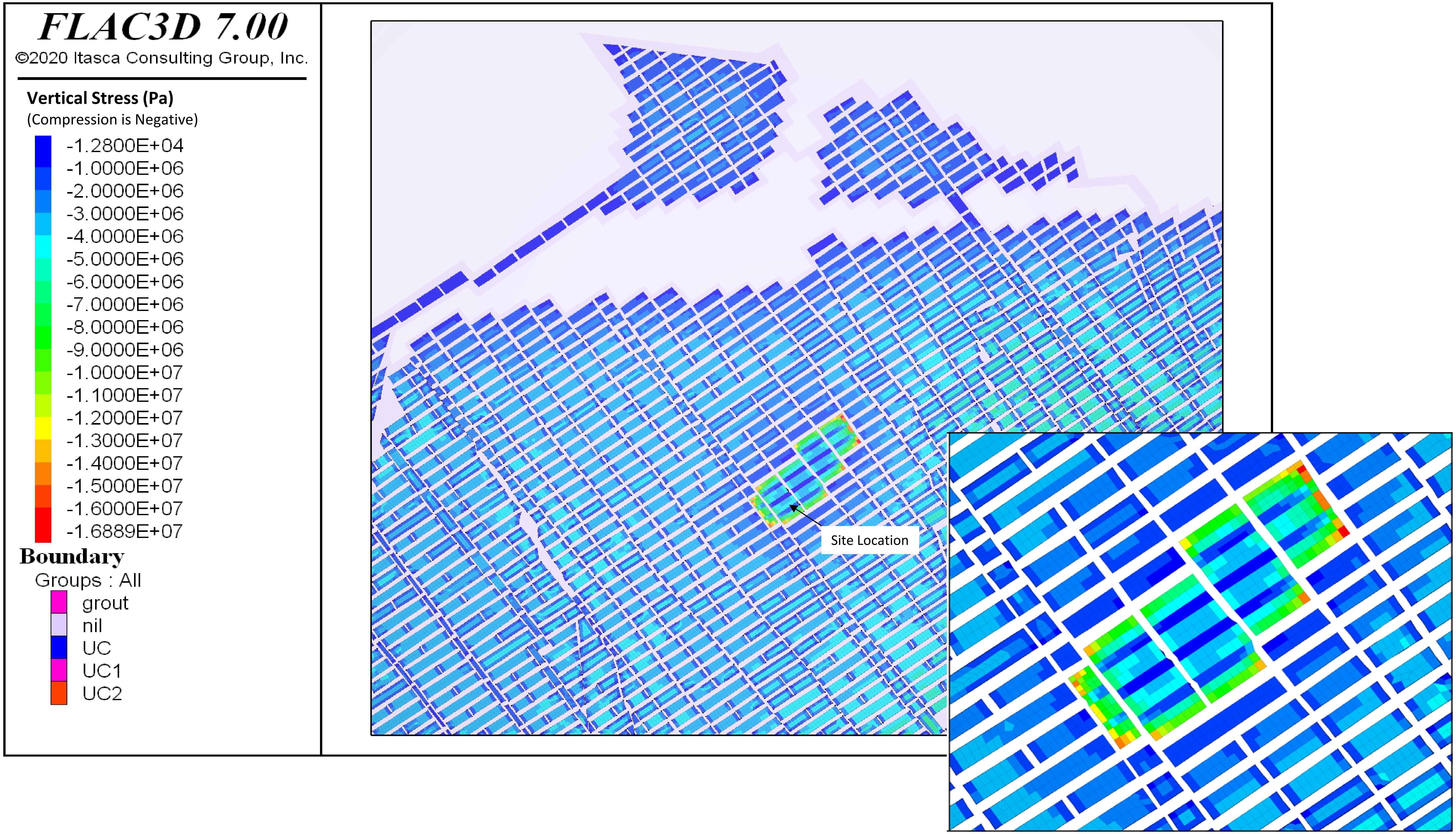


- Pillar Zone 3 (half stiffness)
- Pillar Zone 2 (UnSoftened)
- Pillar Zone 2 (Softened)
- Grout Zone



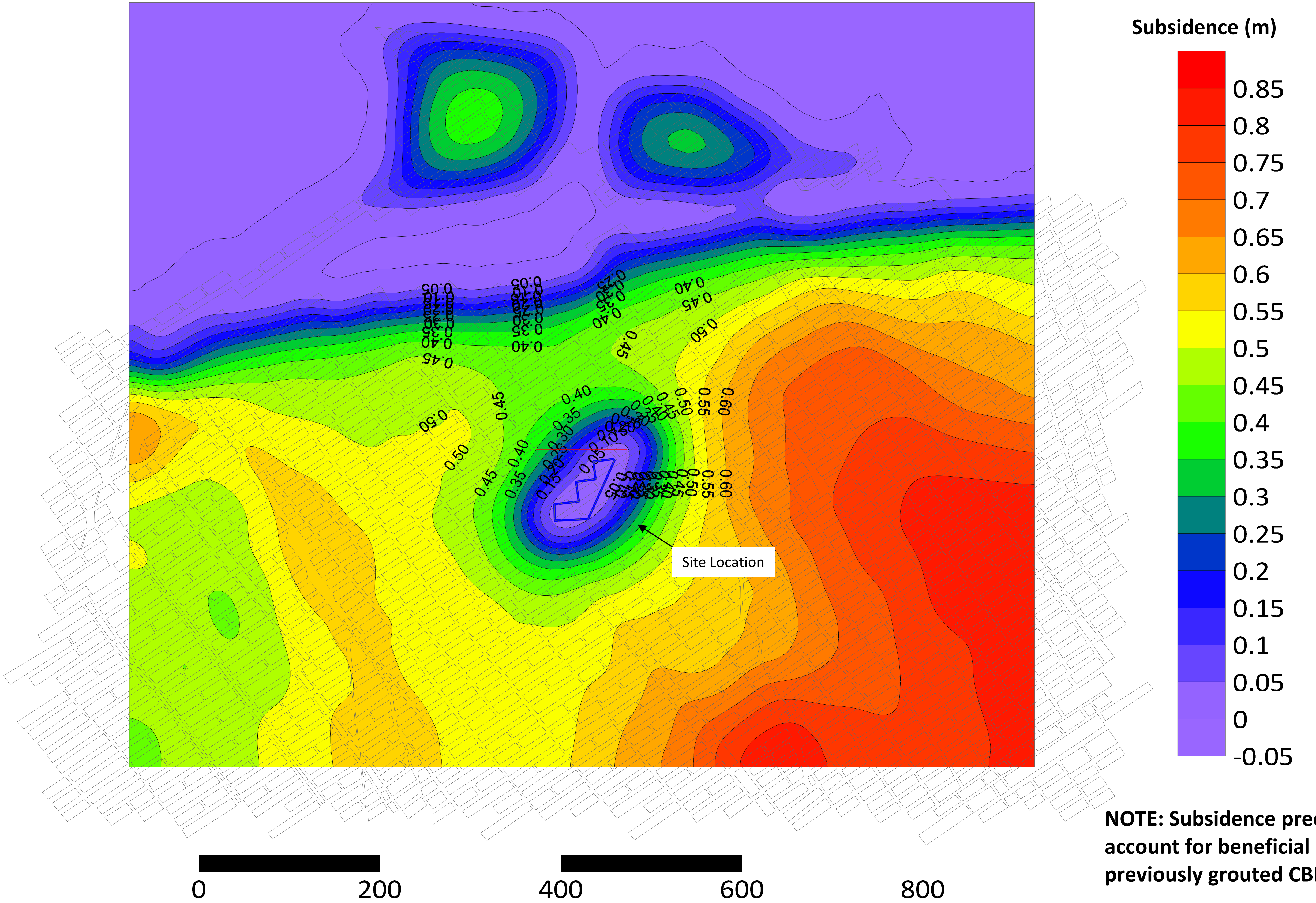
Douglas Partners *Geotechnics / Environment / Groundwater*	CLIENT: Newcastle City Council		TITLE: **Proposed Grout Locations**	PROJECT No:	49737.05
	OFFICE: Newcastle	SCALE NTS	**Newcastle Art Gallery - Proposed Alterations and Additions**	DRAWING No:	9
	DATE: 26 Jul 2021	DRAWN BY: RSM	**1 Laman Street, Newcastle**	REVISION:	2

Flac3D predicted Pillar Stresses



Douglas Partners Geotechnics / Environment / Groundwater	CLIENT: Newcastle City Council		TITLE: **Flac3D predicted Pillar Stresses**	PROJECT No:	49737.05
	OFFICE: Newcastle	SCALE NTS	**Newcastle Art Gallery - Proposed Alterations and Additions**	DRAWING No:	10
	DATE: 26 Jul 2021	DRAWN BY: RSM	**1 Laman Street, Newcastle**	REVISION:	2

Predicted Vertical Subsidence with Grout (m)



NOTE: Subsidence predictions do not account for beneficial effects from previously grouted CBD sites

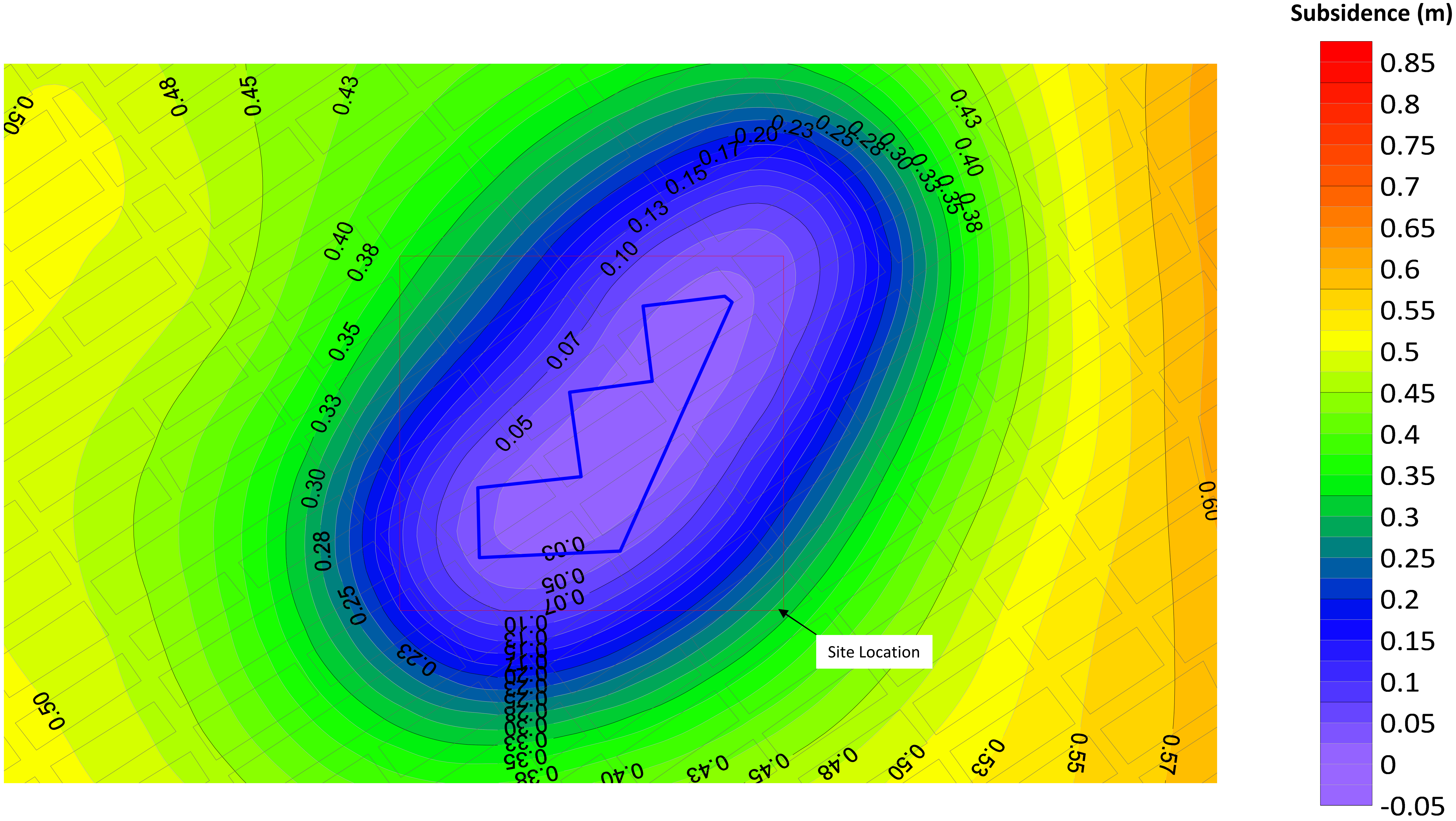
Douglas Partners
Geotechnics / Environment / Groundwater

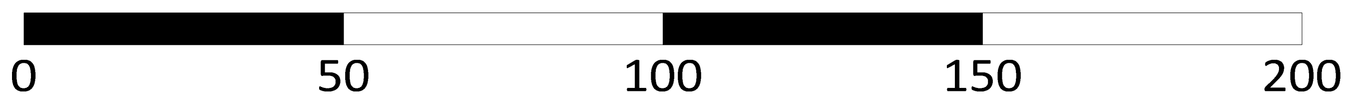
CLIENT:	Newcastle City Council		
OFFICE:	Newcastle	SCALE	As Shown
DATE:	26 Jul 2021	DRAWN BY:	RSM

TITLE: **Predicted Vertical Subsidence with Grout (m)**
Newcastle Art Gallery - Proposed Alterations and Additions
1 Laman Street, Newcastle

PROJECT No:	49737.05
DRAWING No:	11
REVISION:	2

Predicted Vertical Subsidence (m) with Grout

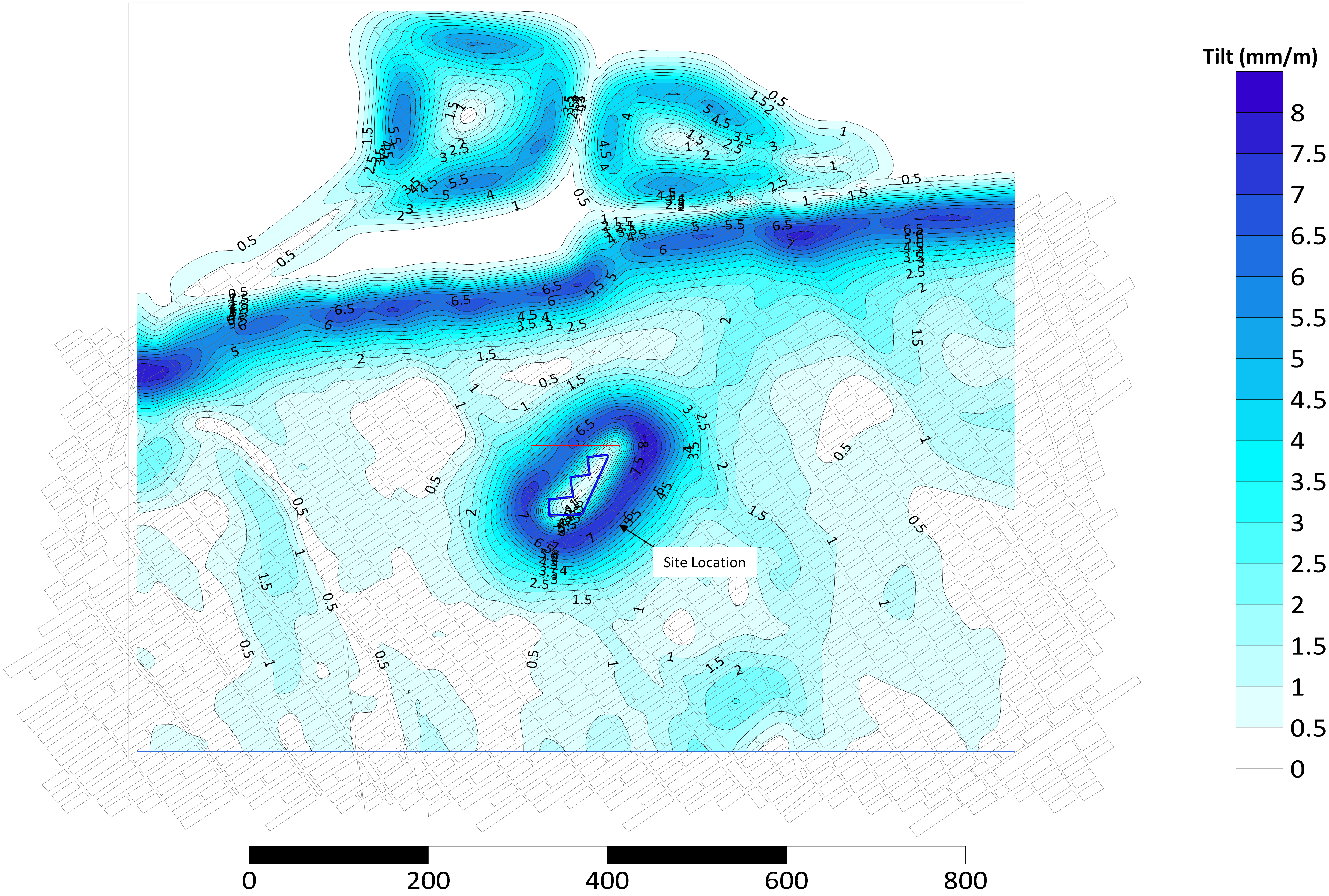




NOTE: Subsidence predictions do not account for beneficial effects from previously grouted CBD sites

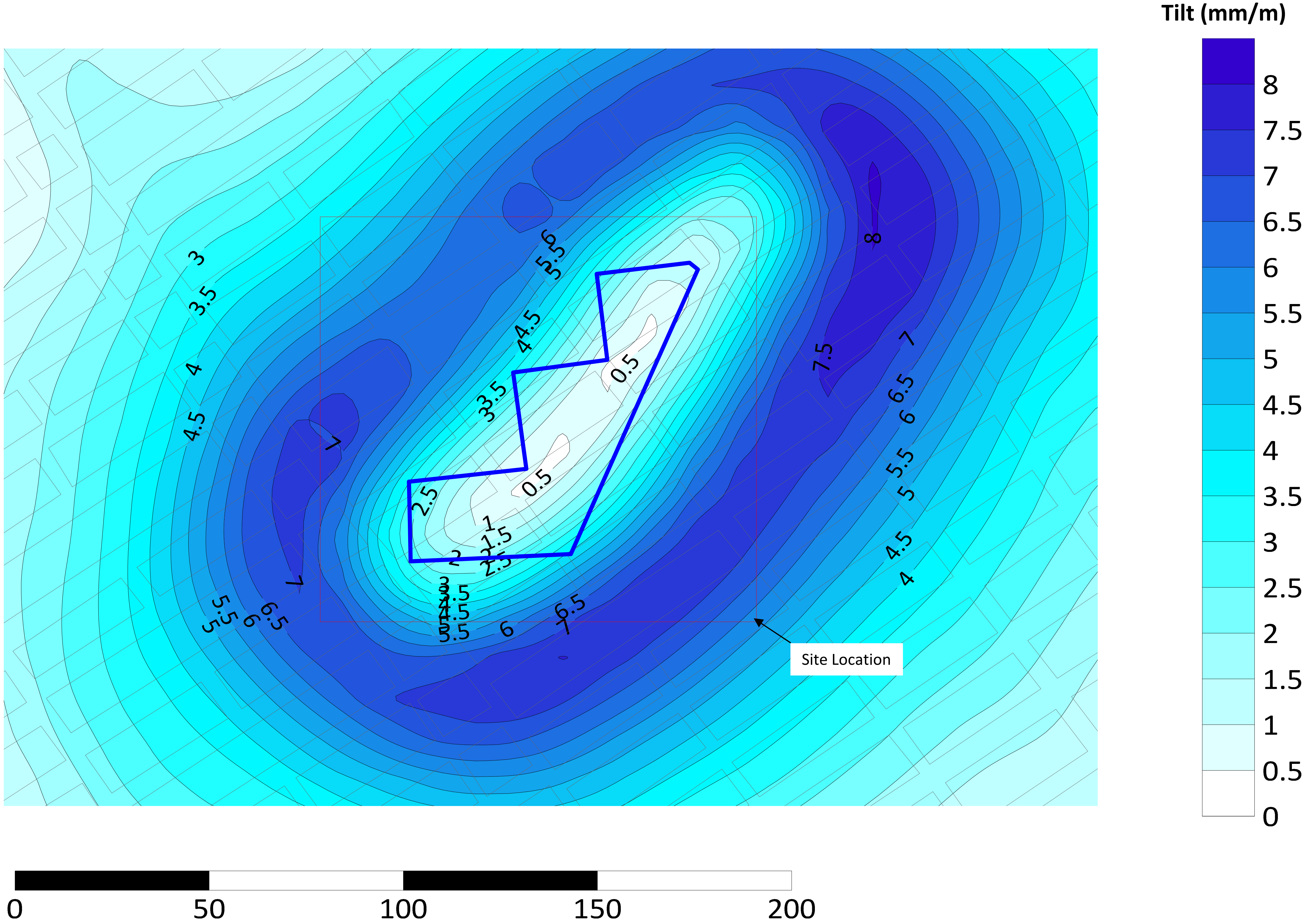
Douglas Partners *Geotechnics / Environment / Groundwater*	CLIENT: Newcastle City Council		TITLE: **Predicted Vertical Subsidence with Grout (m)**	PROJECT No: 49737.05
	OFFICE: Newcastle	SCALE: As Shown	**Newcastle Art Gallery - Proposed Alterations and Additions**	DRAWING No: 11b
	DATE: 26 Jul 2021	DRAWN BY: RSM	**1 Laman Street, Newcastle**	REVISION: 2

Predicted Tilt (mm/m) with Grout



Douglas Partners Geotechnics / Environment / Groundwater	CLIENT: Newcastle City Council		TITLE: Predicted Tilt with Grout (mm/m)	PROJECT No:	49737.05
	OFFICE: Newcastle	SCALE: As Shown	Newcastle Art Gallery - Proposed Alterations and Additions	DRAWING No:	12
	DATE: 26 Jul 2021	DRAWN BY: RSM	1 Laman Street, Newcastle	REVISION:	2

Predicted Tilt (mm/m) with Grout



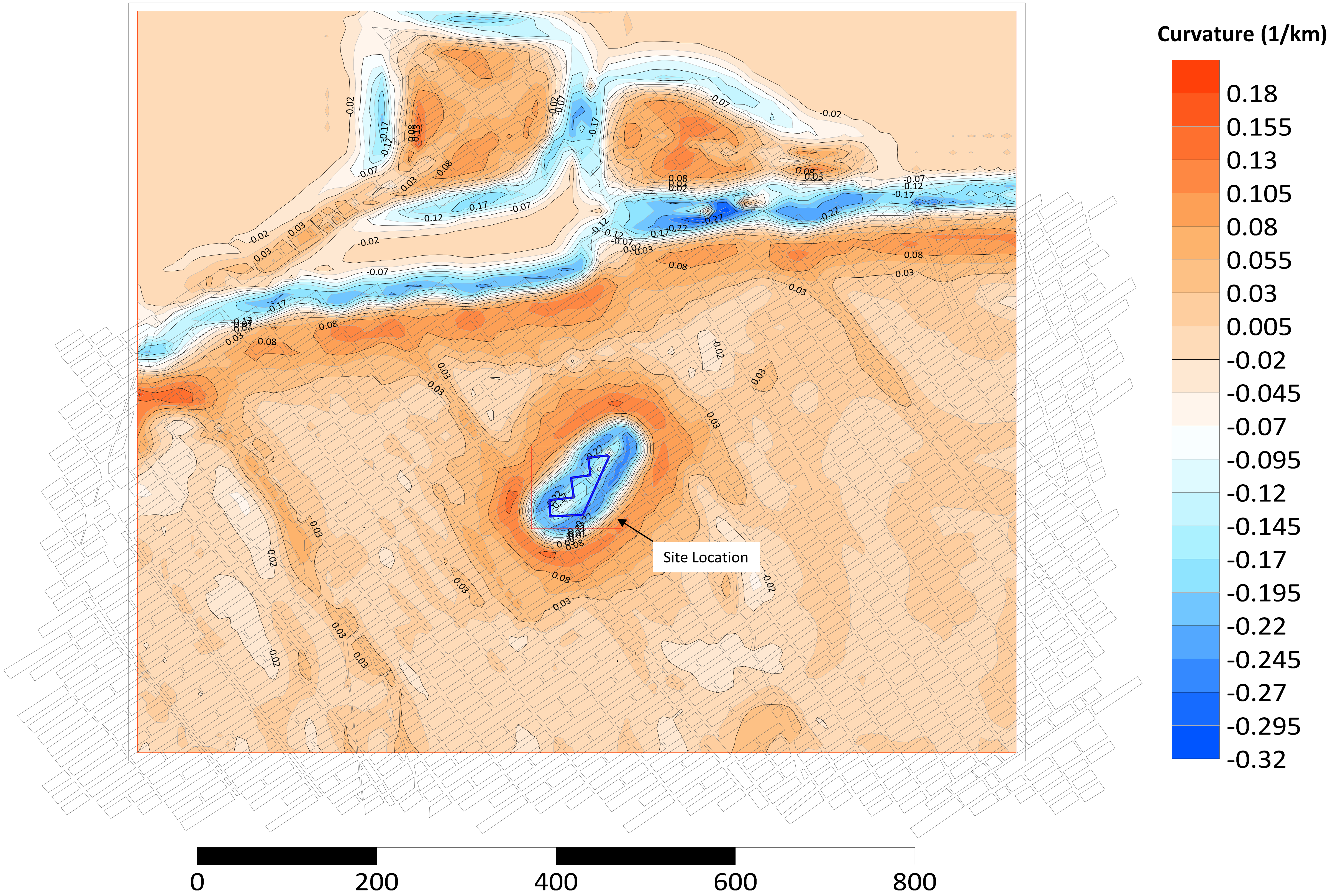
Douglas Partners
Geotechnics / Environment / Groundwater

CLIENT:	Newcastle City Council		
OFFICE:	Newcastle	SCALE	As Shown
DATE:	26 Jul 2021	DRAWN BY:	RSM

TITLE: **Predicted Tilt with Grout (mm/m)**
Newcastle Art Gallery - Proposed Alterations and Additions
1 Laman Street, Newcastle

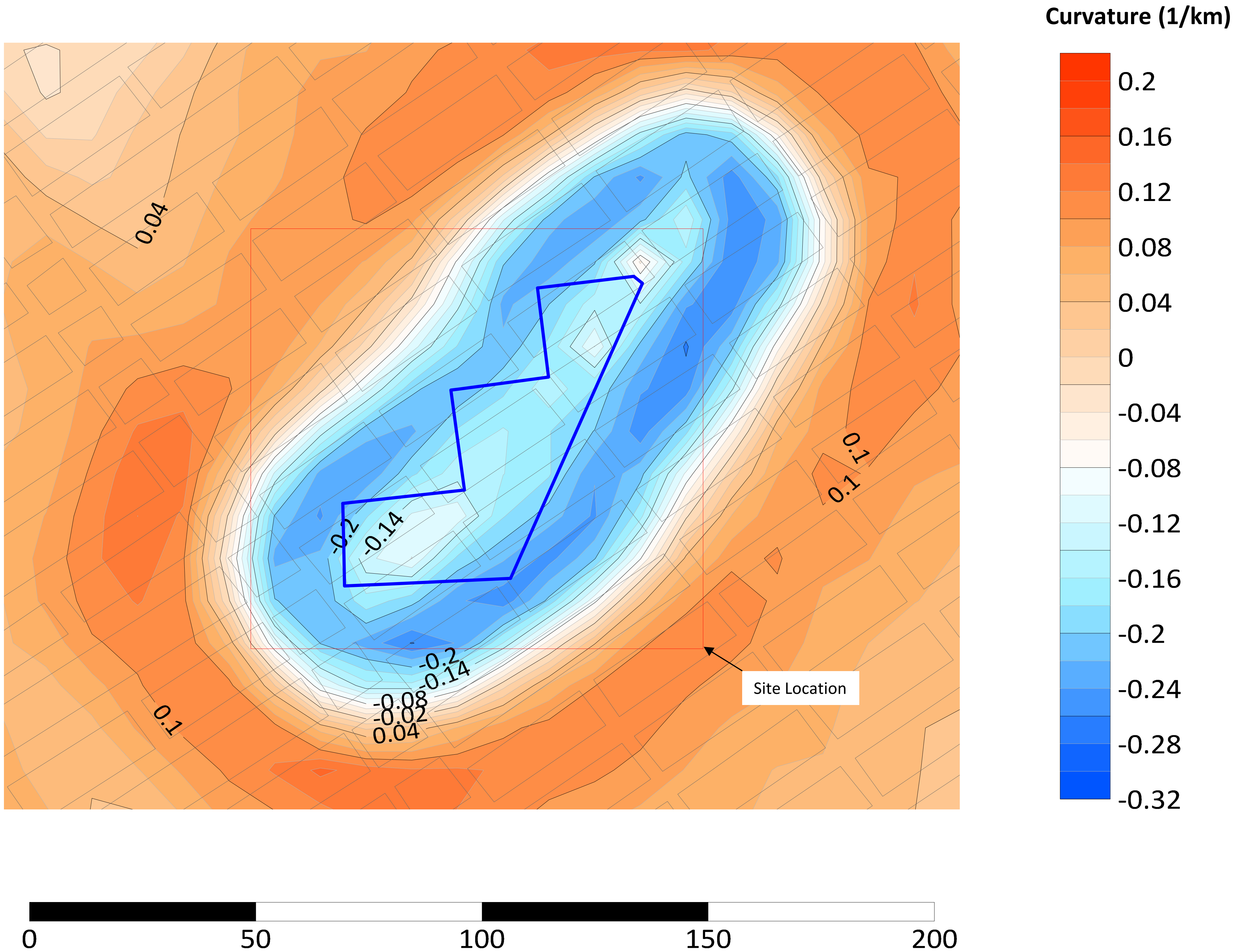
PROJECT No:	49737.05
DRAWING No:	12b
REVISION:	2

Predicted Curvature (1/km) with Grout



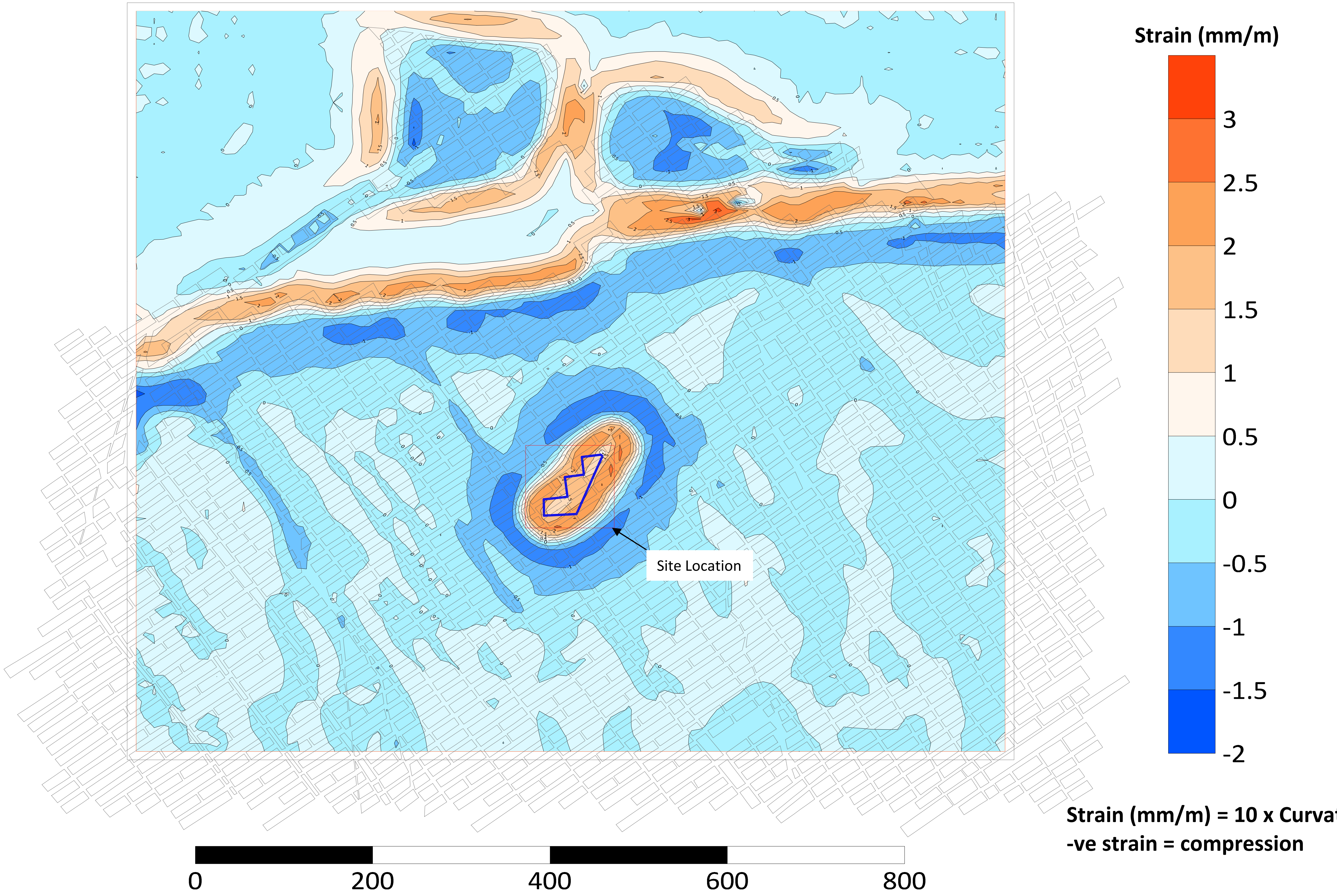
Douglas Partners Geotechnics / Environment / Groundwater	CLIENT: Newcastle City Council		TITLE:	**Predicted Curvature with Grout (1/km)**	PROJECT No: 49737.05
	OFFICE: Newcastle	SCALE As Shown		**Newcastle Art Gallery - Proposed Alterations and Additions**	DRAWING No: 13
	DATE: 26 Jul 2021	DRAWN BY: RSM		**1 Laman Street, Newcastle**	REVISION: 2

Predicted Curvature (1/km) with Grout



Douglas Partners Geotechnics / Environment / Groundwater	CLIENT: Newcastle City Council		TITLE: **Predicted Curvature with Grout (1/km)**	PROJECT No:	49737.05
	OFFICE: Newcastle	SCALE As Shown	**Newcastle Art Gallery - Proposed Alterations and Additions**	DRAWING No:	13b
	DATE: 26 Jul 2021	DRAWN BY: RSM	**1 Laman Street, Newcastle**	REVISION:	2

Predicted Horizontal Strain (mm/m) with Grout



Strain (mm/m) = 10 x Curvature
-ve strain = compression

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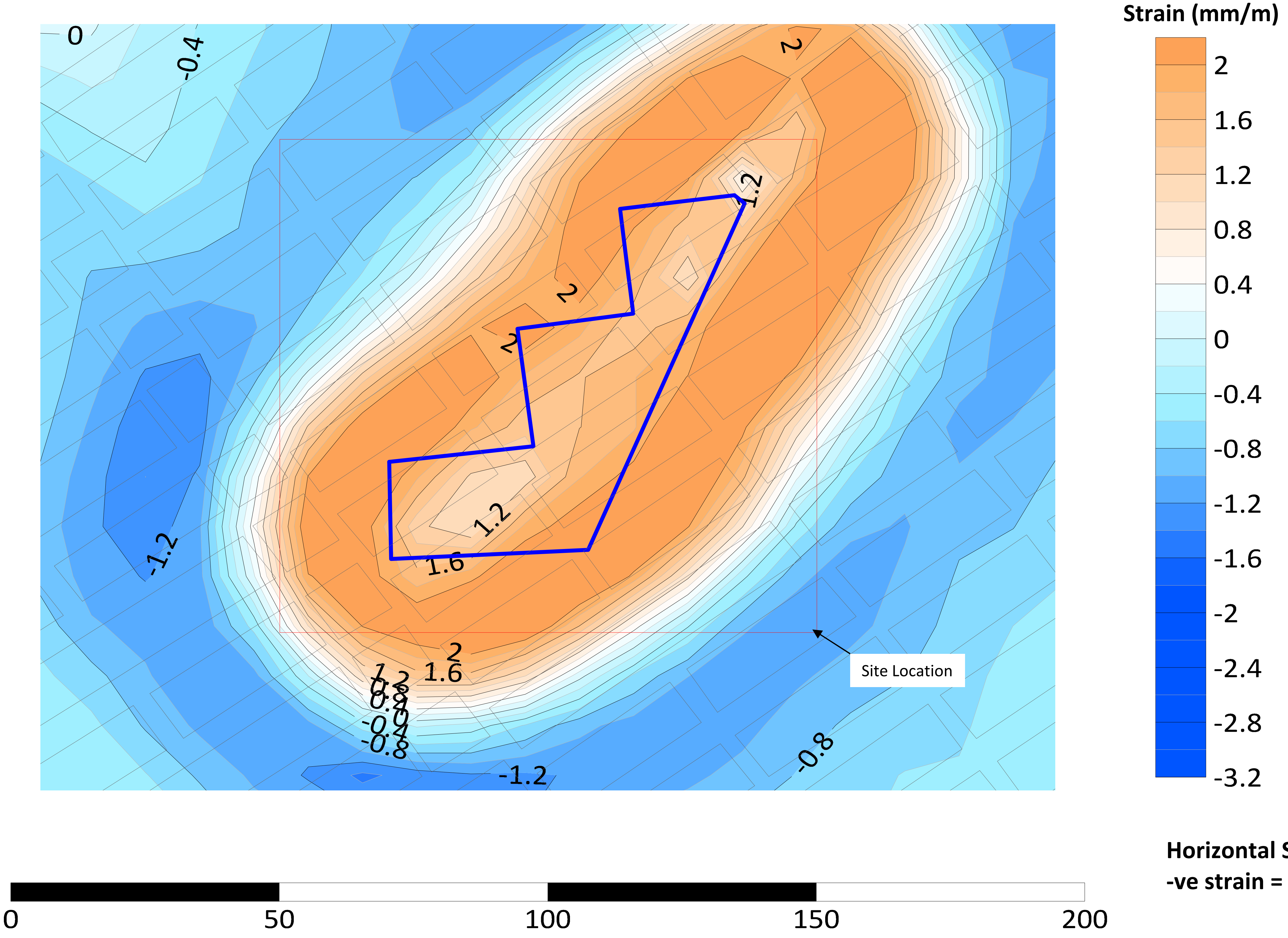
CLIENT: Newcastle City Council		TITLE:	**Predicted Horizontal Strain with Grout (mm/m)**	PROJECT No: 49737.05
OFFICE: Newcastle	SCALE As Shown		**Newcastle Art Gallery - Proposed Alterations and Additions**	DRAWING No: 13b
DATE: 26 Jul 2021	DRAWN BY: RSM		**1 Laman Street, Newcastle**	REVISION: 2

Predicted Horizontal Strain with Grout (mm/m)



Horizontal Strain = 10 x Curvature
-ve strain = compression

Douglas Partners Geotechnics / Environment / Groundwater	CLIENT: Newcastle City Council		TITLE: Predicted Horizontal Strain with Grout (mm/m)	PROJECT No:	49737.05
	OFFICE: Newcastle	SCALE As Shown	Newcastle Art Gallery - Proposed Alterations and Additions	DRAWING No:	14b
	DATE: 26 Jul 2021	DRAWN BY: RSM	1 Laman Street, Newcastle	REVISION:	2