

Before the Board of Inquiry
Waterview Connection Project

in the matter of: the Resource Management Act 1991

and

in the matter of: a Board of Inquiry appointed under s 149J of the Resource Management Act 1991 to decide notices of requirement and resource consent applications by the NZ Transport Agency for the Waterview Connection Project

Statement of evidence of Gavin Alexander (Ground Settlement) on behalf of the **NZ Transport Agency**

Dated: 9 November 2010

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STATEMENT OF EVIDENCE OF GAVIN ALEXANDER ON BEHALF OF THE NZ TRANSPORT AGENCY

INTRODUCTION

- 1 My full name is Gavin John Alexander. I am a Technical Director in Beca Infrastructure Limited's (*Beca*) Geotechnical Group based in Auckland.
- 2 I have the following qualifications and experience relevant to the evidence I shall give:
 - 2.1 I hold a Bachelor of Civil Engineering from the University of Auckland (1986) and a Masters Degree in Soil Mechanics and Engineering Seismology from Imperial College, University of London (1991).
 - 2.2 I am a New Zealand Chartered Professional Engineer, a Fellow of the Institution of Professional Engineers of New Zealand, and a Member of the New Zealand Geotechnical, Structural Engineering and Large Dam Societies.
 - 2.3 I have 28 years experience in geotechnical and civil engineering, and over the past 24 years I have provided geotechnical advice on a wide variety of civil, commercial, industrial, and land development projects in many parts of New Zealand, and in Australia and further afield.
 - 2.4 Particularly relevant projects I have provided advice on include Victoria Park Tunnel (*VPT*) and the New Lynn Rail Trench (*NLRT*) in Auckland, and the Marina South MRT (rail) Station and associated tunnels in Singapore.
 - 2.5 I was the tunnel design manager for the early notice of requirement work for VPT (previously known as the Harbour Bridge to City project), and am the geotechnical verifier for the alliance that is currently designing and building this 400m long cut and cover project. I fulfilled a similar geotechnical verification role through design and construction of the recently completed 1000m long NLRT project. My involvement with the 30m deep Marina South MRT station comprised review of client supplied information and direction and review of geotechnical aspects of a design/build tender design prepared by my colleagues in Singapore.
 - 2.6 Each of these examples required detailed assessment of the likely ground water effects of construction and operation (undertaken by my colleagues), calculation of the resulting groundwater drawdown related settlement, calculation of structural deflections and assessment of the resulting ground

movement, assessment of the likely effects on structures and development of a monitoring system to manage the consequent effects. These considerations are shared with the State Highway 20 Waterview Connection Project.

- 3 My evidence is given in support of notices of requirement and applications for resource consents lodged with the Environmental Protection Authority (*EPA*) by the NZ Transport Agency (*NZTA*) on 20 August 2010 in relation to the Waterview Connection Project (*Project*). The Project comprises works previously investigated and developed as two separate projects, being:
 - 3.1 The State Highway 16 (*SH16*) Causeway Project; and
 - 3.2 The State Highway 20 (*SH20*) Waterview Connection Project.
- 4 I am familiar with the area that the Project covers, and the State highway and roading network in the vicinity of the Project.
- 5 I have read the Code of Conduct for Expert Witnesses as contained in the Environment Court Consolidated Practice Note (2006). My evidence has been prepared in compliance with that Code in the same way as I would if giving evidence in the Environment Court. In particular, unless I state otherwise, this evidence is within my sphere of expertise and I have not omitted to consider material facts known to me that might alter or detract from the opinions I express.

SCOPE OF EVIDENCE

- 6 My evidence will deal with the following:
 - 6.1 Executive summary;
 - 6.2 Background and role;
 - 6.3 Summary of assessment of ground settlement effects;
 - 6.4 Post-lodgement events;
 - 6.5 Comments on submissions;
 - 6.6 Comments on s149G Report by the ARC;
 - 6.7 Proposed ground settlement conditions; and
 - 6.8 Conclusions.

EXECUTIVE SUMMARY

- 7 Ground settlements resulting from the construction of the Waterview Connection Project and the resulting potential for damage to buildings and infrastructure have been assessed under my direction.
- 8 The expected ground settlements result from the combination of ground water changes (consolidation settlement) and soil and rock response to excavation (mechanical settlement). The settlement assessment is closely linked to the assessment of groundwater effects. It is based on the same geologic model as, and uses the outputs from, the ground water analysis in the calculation of consolidation settlement. Ground settlements have been calculated for a particular tunnel alignment and construction methodology. The settlements are based on conservative assumptions, to provide an upper bound measure of the resulting magnitude and lateral extent of settlement resulting from the Project. Maximum settlement of up to 350mm is calculated. The zone of measurable settlement typically extends some 400m east and 200m west of the tunnels.
- 9 The effects of settlement on buildings have been assessed using a proven international methodology which considers both the deflection ratio (degree of curvature) and the horizontal strain along selected cross sections. These are the same cross sections used for calculation of the ground water effects.
- 10 Potential settlement Damage Categories have been assigned in accordance with the adopted methodology, and range from Category 0 – Negligible to Category 4 – Severe. The great majority of the buildings in the study area fall in Category 0 – Negligible to no damage expected. Three properties fall in Category 1 – Very slight damage (fine cracks). Sixteen properties lie within Category 2 – Slight damage (cracks easily filled, some external repointing needed to ensure weather tightness). A further sixteen properties are located in Category 3 – Moderate damage (cracks require opening up to repair, weather tightness often impaired). Seven of these lie within the designation. Three properties fall in Category 4 – Severe damage (extensive repair work required) and all lie within the designation.
- 11 Buildings that fall in Damage Category 3 – Moderate, or 4 – Severe and that are to remain occupied during construction, will be subject to ongoing condition assessment, monitoring and mitigation to ensure their safety and suitability for occupation.
- 12 The effects of settlement on infrastructure (buried services, roads, rail, and surface drainage) have generally been assessed by considering surface gradient changes and the likely effects on

functionality. Specific assessment has been made for particular buried sewers and watermains, and the resulting effects are assessed to be minor to negligible. The effects on surface infrastructure are assessed to be negligible.

- 13 Monitoring of ground settlement, and in some areas horizontal movement, and of building condition is set out in the Settlement Effects Monitoring Plan (*SEMP*), and in the proposed ground settlement conditions. The results of this monitoring, and of relevant groundwater monitoring, will be used to regularly update the settlement estimates and the building damage assessment. This ongoing monitoring will give early warning of areas where the settlement effects may be greater than predicted and is the primary tool for managing ground settlement effects.
- 14 A variety of mitigation measures are available for the different forms of construction (to reduce settlement) and potentially affected features (to repair the effects of settlement). These are described in the *SEMP*.

BACKGROUND AND ROLE

- 15 The NZTA retained Beca as part of a consortia team to assist with investigation and reporting on the Project, including scheme design engineering, environmental and planning professional services. A team of engineers from Beca prepared the Assessment of Ground Settlement Effects Report (*Report*). That team consisted of:
 - 15.1 James Burr: Technical Director – Geotechnical Engineering;
 - 15.2 Robert Hopkins: Civil Engineer; and
 - 15.3 Aaron Beer: Technical Director – Structural Engineering.
- 16 My role was to guide development of the assessment methodology and to peer-review the Report.
- 17 Assessment of ground settlement requires consideration of the magnitude of ground movements resulting from groundwater changes (known as consolidation settlement), and of movement resulting directly from excavation (known as mechanical settlement). Groundwater changes from the Assessment of Groundwater Effects Report (Technical Report G.7) have formed the basis of the consolidation settlement calculations. Mechanical settlement calculations were undertaken by geotechnical engineers from Tonkin and Taylor¹, and are summarised in Appendices B to D of Technical Report G.13. I have relied on their work when preparing my assessment and evidence.

¹ Tonkin and Taylor engineers: Nick Speight, Neil Korte and Sjoerd Van Ballegooy.

- 18 Ground settlement effects comprise not just the amount of surface movement but, more importantly, the effects of that movement on buildings and infrastructure. Those assessments were made by my geotechnical, civil and structural colleagues at Beca.
- 19 The Report was lodged with the EPA on 20 August 2010 as part of the overall Assessment of Environmental Effects (*AEE*) (specifically, Part G, Technical Report G.13).²
- 20 The Report included a Settlement Effects Management Plan (*SEMP*) which identifies the proposed approach for monitoring and, if required, mitigation of settlement effects associated with the Project.³ This approach involves the coordinated collection and integrated assessment of groundwater and surface movement monitoring data by an independent team, with "live" updating of damage category forecasts and the triggering of appropriate responses. In my opinion, this reflects good international practice in managing ground settlement effects.
- 21 The Report was supported by Geotechnical Factual Reports also lodged with the AEE (see Part G), being:
- 21.1 Report No. G.28 (500 series), Volumes One to Three; and
- 21.2 Report No. G.29 (700 series), Volumes One to Three.
- 22 The Report was informed by, and relies upon, other technical reports lodged with the EPA in support of the Project, those reports being primarily:
- 22.1 Assessment of Groundwater Effects (Technical Report G.7); and
- 22.2 Geotechnical Interpretive Report (Technical Report G.24).
- 23 Groundwater lowering in soils (from tunnel and other excavation) causes clayey soils to settle by the mechanism known as consolidation. Groundwater related settlement (consolidation) contributes a significant proportion of the total settlement resulting from tunnel construction, and results in the most widespread effects. Consequently, the Assessment of Groundwater Effects Report is of fundamental importance to the assessment of settlement. My team has used the findings from that report to calculate consolidation settlements. Both the Assessment of Ground Settlement Report and the Assessment of Groundwater Effects

² Shortly after lodgement, typographical errors were corrected and clarifications made to Technical Report G.13, which was replaced with a report of the same name, dated August 2010.

³ See Appendix H of Technical Report G.13.

Report consider the same representative cross sections drawn across the tunnel alignment.

SUMMARY OF ASSESSMENT OF GROUND SETTLEMENT EFFECTS

- 24 In this section of my evidence I will briefly describe the key points of the Report.

The Project and the existing environment

- 25 The Project includes providing a new section of SH20 through a combination of surface and tunnelled road between the Great North Road and the Maioro Street Interchanges. The proposed cut and cover tunnel is 450m long; the twin driven tunnels 2.1km long.
- 26 The area concerned is predominately residential in nature and includes the Unitec campus and a few commercial buildings. The buildings are typical of older residential buildings in Auckland. There are some historic structures within the Unitec campus.
- 27 The services are typical of a suburban location although some sewers and a large watermain pass through the area. The western railway line crosses the alignment. Other features are the Oakley Creek and several historic landfills in reserve areas near the Creek.

The Report

- 28 The Report presents the results of an assessment of the potential magnitude and effects of ground settlement (*settlement*) due to the construction and operation of the SH20 northern tunnel portal, cut and cover tunnel, driven tunnels and southern portal. The settlement effects associated with two retaining walls that have existing buildings nearby were also assessed.
- 29 In the Report, the sources of settlement are detailed and the magnitude of settlement calculated to assess the settlement effects on buildings, services, infrastructure and other features. A monitoring regime and potential mitigation measures are also provided in the accompanying SEMP.
- 30 It is important to note that the Report, and the accompanying SEMP focuses predominantly on the damage potential arising from settlement (i.e. the effects), rather than the quantum of settlement itself.

Sources of settlement effects⁴

- 31 There are three sources of settlement associated with the construction and operation of the Project, as described below.

⁴ Refer to paragraph 2.3, page 4 of Technical Report G.13.

- 32 *Mechanical settlement due to extraction of material:* Extraction of material for the driven tunnels will entail the removal of supporting rock and the subsequent relaxation of the rock and soil above the excavation. The settlement due to physical extraction will occur relatively quickly following excavation of the driven tunnels and will be concentrated over the tunnel alignments.
- 33 *Mechanical settlement due to wall movement:* Mechanical settlement due to physical movement of the retaining walls results from the lateral movement of the retaining walls as they take the load as one side is excavated and/or the other side is loaded. This settlement will also occur relatively quickly following loading of the walls, and will be concentrated in the areas behind the retaining walls.
- 34 *Consolidation of the ground due to groundwater extraction:* This consolidation is caused by the reduction in porewater pressure within the overlying soil as water seeps into an excavation. Consolidation is time-dependant and based on the location and permeability of the excavation at any one time.
- 35 Consolidation settlements have been calculated using “base case” two-dimensional (2D) groundwater modelling results that are presented in the Assessment of Groundwater Effects Report (Technical Report G.7). The base case scenario was adopted (in preference to the various sensitivity cases) as it is considered to represent the most likely groundwater effects arising from the Project.

Methodology of calculating settlement effects⁵

- 36 The estimated settlements from the three sources were derived separately and then combined. The settlements were all calculated at a consistent series of cross sections along the alignment and combined to produce total settlement results at critical stages of construction and operation.⁶ The cross sections considered and the total estimated ground settlements are shown in Figure E14 of the Report, attached to my evidence as **Annexure A**.
- 37 The magnitude of estimated settlement is considered to be conservative (i.e. likely settlement is over-stated) due to the parameters used in the calculations:
- 37.1 In particular, the mechanical settlement design parameters use stiffness values (Young’s Modulus, E) which have a significant conservative bias;

⁵ Refer to section 4, page 13 of Technical Report G.13.

⁶ Refer to Appendix A, Figure A-2 (Technical Report G.13) for a Cross Section Location Plan.

37.2 The consolidation settlement analysis assumes that the full effect of the calculated groundwater pressure changes translates into settlement. In fact, consolidation settlements take time to develop in response to groundwater changes (as pore water seeps out of the affected soil mass). The construction of the tunnel liner will initiate recharge, and thus reverse groundwater changes before they cause the full amount of calculated settlement; and

37.3 The ground movements are estimated without taking into account the stiffness of the structures which will in many cases tend to inhibit ground movement. This is explained in Kastner et al⁷ as follows:

"The presence of a building is assumed to have no effect on the settlement prediction and any damage parameters are calculated using the predicted greenfield movements. This is clearly an over-simplification of reality as the stiffness of the building affects its deformation."

38 For the twin driven tunnels there are two critical stages:⁸

38.1 Day 13 of each 50m advance, when the first 50m of (northbound) tunnel has been excavated and shotcreted; and

38.2 Day 42 when the second tunnel has been excavated and shotcreted to the same point and the mechanical settlement from both tunnels combines with the groundwater drawdown to produce the greatest total settlement.

39 Both of these driven tunnel scenarios occur during construction.

40 The portals and retaining walls have a single critical stage, which is the long-term, when all settlements are complete and consolidation has occurred.

41 The effects on buildings were assessed using an internationally accepted method specifically designed for tunnel construction.⁹ The method determines the curvature and horizontal strain in a building and plots these values against criteria to assess the likely effect on a structure. The classification of potential effects (Damage Category) is then determined. The method has been derived for

⁷ Kastner R, Kjekstad O, and Standing J, 2003. "Avoiding damage caused by soil-structure interaction: Lessons learnt from case histories." Thomas Telford, London.

⁸ Refer to paragraph 4.6, page 24 of Technical Report G.13.

⁹ Refer to paragraph 4.7.1, page 25 of Technical Report G.13.

unreinforced masonry buildings, so can be considered conservative for timber framed and reinforced concrete buildings.

- 42 The effects on local services and transportation infrastructure were assessed by calculating the change in their gradient as a result of the settlement and then determining whether that change could damage each item being assessed. The effects on Oakley Creek and the old landfills were assessed by considering the total settlement and changes in gradient.¹⁰

Settlement effects

- 43 The settlement effects estimated follow the anticipated trough shape along the alignment, with the greatest settlements occurring over the driven tunnel alignment and then reducing as they extend several hundred metres each side.¹¹
- 44 The effects assessment predicts that there will be negligible effects on the vast majority of buildings along the alignment, with a limited number of areas of more than negligible effects. In these cases, predicted damage is typically either "very slight" or at worst "slight". To give an indication, "slight" damage is characterised by visible cracks which are easily filled, and slight sticking of doors and windows.¹² Plans have been prepared showing calculated building damage categories derived from the calculated settlements, and these are reproduced and attached to my evidence as **Annexure B**.
- 45 Some properties along Great North Road from Alford Street northwards fall into Damage Category 3 (moderate damage) and greater. These buildings are within the designation for the Project. If any of these buildings remain in place, they will require ongoing detailed assessments and monitoring to establish the extent of the effects and any mitigation required.¹³
- 46 One property on Great North Road (No. 1590A) and eight properties in Waterview Downs (Nos. 16, 18, 20, 22, 26, 28, 30 and 32) also lie in zones of moderate predicted damage (Damage Category 3). These buildings are to remain in place, and will be subject to ongoing detailed assessment and monitoring. This ongoing assessment will commence with a detailed pre-construction inspection, and will include periodic inspection during critical stages

¹⁰ Refer to paragraph 4.7.4, page 28 of Technical Report G.13.

¹¹ Refer to **Annexure A** for a plan showing the estimated extent and magnitude of settlements.

¹² Refer to page 27 of Technical Report G.13 for a table categorising building damage, and to Appendix G, Figures G-1 to G-4 of that Report for a contour plan indicating the damage categories derived from the estimated settlements (attached to my evidence as **Annexure B**).

¹³ Refer to paragraph 5.3.2.9, page 40 of Technical Report G.13 and page 10 of the SEMP.

of tunnel construction, and monitoring of settlement and/or wall inclination, and is identified in the proposed conditions (see below).

- 47 The settlement effects on the majority of services were assessed as being negligible, with the potential for some minor effects on a few specific services. These services will be subject to ongoing monitoring.¹⁴
- 48 Similarly, the effects of the estimated settlements on transportation infrastructure have been assessed as negligible.¹⁵
- 49 The effects of the estimated settlements on Oakley Creek and the landfills were assessed as being negligible or minor.¹⁶

Monitoring¹⁷

- 50 The proposed monitoring is described in detail in the Report and SEMP. It comprises horizontal and vertical monitoring of survey marks, condition assessments of nearby buildings and specific monitoring of retaining walls and services. As discussed in the evidence of Ms Ann Williams, monitoring of groundwater levels and their changes can provide an early warning of potential consolidation settlements. Groundwater monitoring forms part of the overall monitoring strategy proposed for the Project.
- 51 The frequency of monitoring will depend on the proximity of the object being monitored to the active construction area, the stage of construction and the results of previous monitoring or surveys.

Mitigation¹⁸

- 52 Current assessment indicates that only minor mitigation is required in isolated locations. However, the Report does present more comprehensive mitigation measures to cover the unlikely scenario of more damage occurring than predicted.
- 53 Building mitigation includes repair of non-structural defects once settlement is complete and the immediate repair of any issues that are structural or will affect the weather tightness of the buildings.

¹⁴ Refer to paragraph 5.3.3, page 40 of Technical Report G.13 and page 10 of the SEMP. These services are the Watercare Orakei No.9 trunk sewer which weaves along the length of the driven tunnel alignment, a Metrowater sewer near the northern tunnel portals, the Watercare Huia No.2 watermain which follows New North Road, and various smaller sewage, stormwater, water, gas, power and telecommunications services along Great North Road, New North Road, in Albie Turner Fields and in the vicinity of the South Tunnel Portal.

¹⁵ Refer to paragraph 5.3.4, page 42 of Technical Report G.13.

¹⁶ Refer to paragraph 5.3.5, page 42 of Technical Report G.13.

¹⁷ Refer to section 6.1, page 44 of Technical Report G.13 and page 14 of the SEMP.

¹⁸ Refer to paragraph 6.2, page 49 of Technical Report G.13 and page 20 of the SEMP.

- 54 Services mitigation depends on the type of service and its construction but includes crack repairs, diversion, relining, support and replacement. Road and rail could be mitigated by relatively minor surface reconstruction methods and the landfills by physical retaining works if required.

Conclusions in the assessment¹⁹

- 55 The effects from the estimated settlements caused by the tunnel construction are considered to be typically negligible, with isolated areas of very slight, slight and moderate building damage predicted beyond the designation.
- 56 Monitoring will be carried out to confirm the above, to quantify any actual damage and to allow for early warning of areas where the settlement effects may be greater than predicted. Mitigation measures are readily available for the predicted levels of damage and in the unlikely event that greater settlement effects occur.
- 57 The SEMP identifies practicable options for the management and monitoring of settlement effects and provides a framework for the development of settlement control practices and procedures to manage and minimise the effects of settlement on buildings and services. Subject to the proposed ground settlement conditions (see below) being followed, the estimated damage caused by settlements resulting from the tunnel construction is considered to be typically negligible.

POST-LODGE MENT EVENTS

- 58 Ms Williams, in her evidence, describes the production of a short addendum Groundwater Report (Appendix 4 to Technical Report G.7) that she prepared to provide clarity on the interpretation of groundwater systems and the associated model calibration on the western side of the tunnel alignment.
- 59 Ms Williams' additional groundwater assessment indicated negligible change in consolidation settlement at ch3400. A larger change in settlement was calculated at ch2750, with maximum consolidation (and hence total) settlements increasing by some 26mm. A maximum total settlement of 124mm was calculated for the groundwater case considered, compared to 98mm for the base case.
- 60 The building damage category was reassessed for the revised settlement profile, and did not result in any changes to the zones of potential damage resulting from the tunnel construction. Estimated damage in this area remains in Category 0 (i.e. negligible).

¹⁹ Refer to section 7, page 53 of Technical Report G.13.

- 61 Since the preparation of Technical Report G.13, I have had additional sensitivity analyses undertaken to satisfy myself that the extents of particular zones of potential building damage represent an upper bound (i.e. that other combinations of parameters, or of the different mechanisms of movement do not result in worse or more extensive effects than those calculated in Technical Report G.13). The sensitivity cases studied included:
- 61.1 Mechanical settlement only – modelling delayed appearance of consolidation effects at the surface, potentially resulting in sharper curvature at the ground surface, and possibly greater building damage;
 - 61.2 Varying the representative building length – potentially changing the sensitivity to ground curvature; and
 - 61.3 Varying the coefficient of volume compressibility (m_v , inverse of stiffness) over the range of laboratory test results to match the particular descriptions on the bore logs to assess sensitivity to local changes in soil characteristics within a particular unit.
- 62 The results of these sensitivity analyses, and others undertaken in the course of the initial analysis, demonstrated that the settlement profiles calculated for the base case, and the consequent building damage category assessment, are conservative. In other words, they represent a reasonable worst case, and in my view over-state the potential effects of ground settlement in the Project.

COMMENTS ON SUBMISSIONS

I have read submissions lodged on the Project that raise ground settlement or related issues relevant to my area of expertise. Submitters have raised a variety of ground settlement concerns. Where issues have already been dealt with in my evidence or Report, I do not propose to address them again here. Accordingly, in this section of my evidence I will address submissions that raise issues not already covered or that require further response.

Auckland Regional Council²⁰

- 63 The Auckland Regional Council (ARC) raises concerns regarding:
- 63.1 The potential effect of ground settlement on the integrity of the Phyllis Street Reserve landfill cap;²¹
 - 63.2 Assessment against and compliance with the Proposed Auckland Regional Plan: Air, Land and Water (ALWP);²²

²⁰ Submitter No. 207.

²¹ See paragraphs 4.8.6 and 4.8.7, Submission No. 207.

63.3 The need for settlement limits to be nominated to provide an early warning of potential problems; and

63.4 An appropriate monitoring and reporting system to be developed and approved by the Auckland Council.²³

Phyllis Street Reserve landfill cap

64 The estimated settlement effects at this location are discussed in Section 5.3.5.2 of Technical Report G.13, and are indicated on cross sections drawn at Chainages 3200 and 3400 (Figures E8 and E9 of that Report). Settlement gradients of 1 vertical in 250 horizontal are calculated across the landfill, with the greater settlement occurring on the eastern side (i.e. a slope developing away from Oakley Creek). While the conservatively calculated settlements (of up to 350mm maximum) are not considered large enough to compromise the integrity of the landfill cap, the resulting gradient may cause surface water ponding. This pooling could, if not remedied, locally increase water infiltration rates through the cap. Proposed Groundwater Condition G.7²⁴ provides for surface inspection of the landfill and releveling in areas where cracking or ponding is evident.

65 Monitoring of ground surface movements could be used to provide an indication of the need for releveling work in the Phyllis Street Reserve. In my opinion, such monitoring should be commenced early, to provide a measure of any ongoing settlement that is currently occurring as a result of ongoing decomposition of the landfill material.

Assessment against and compliance with the ALWP

66 Rule 6.4.47(c) of the ALWP requires any proposal to divert groundwater to avoid, remedy or mitigate the resulting ground settlement that may result in adverse effects. Ground settlement effects have been assessed and a management plan drafted.²⁵ The SEMP describes the proposed monitoring programme and presents possible mitigation options, should they be needed. Consequently, in my view, the Project complies with ALWP Rule 6.4.47.

67 Rule 6.5.68 (b) of the ALWP relates to permitted activities and requires that settlement resulting from groundwater diversion does not cause adverse effects on buildings, structures and services. However, Permitted Activity status is not being sought for this aspect of the Project, so this rule (or compliance with it) is not relevant.

²² See paragraphs 4.8.9 – 4.8.11, Submission No. 207.

²³ See paragraphs 4.8.13 – 4.8.17, Submission No. 207.

²⁴ Attached to the evidence of Ms Williams.

²⁵ Refer to the Settlement Effects Management Plan (SEMP), Appendix H of Technical Report G.13.

- 68 Rule 6.5.69(c) of the ALWP relates to diversion of groundwater as a restricted discretionary activity, and requires consideration of any adverse effects on building owners arising from the potential for ground settlement that may result in significant damage to structures, buildings and services. The SEMP describes the proposed monitoring programme and presents possible mitigation options, should they be needed.²⁶

Nomination of settlement limits and monitoring plan approval by the Auckland Council

- 69 Technical Report G.13 provides what I consider to be a reasonably conservative assessment of ground settlements resulting from the construction and operation of the Project. The potential damage to buildings and infrastructure has been assessed based on those calculated ground movements (which have a vertical and horizontal component in some places). The actual ground movements (and resulting damage, if any) will depend on the final method and details of construction, variations in the nature and behaviour of the soil and rock mass surrounding the excavations, and on the sensitivity of the surface structures and infrastructure to movement.

- 70 In my view it is not appropriate, or necessary, to nominate precise settlement limits at this stage. Rather, it is better to identify a reasonable upper bound of damage potential (which is the real effect, as identified in the ALWP Rules 6.4.47 and 6.5.69), and ensure that the appropriate monitoring and response programmes are established to define pre-construction conditions, refine and update damage predictions as the Project proceeds, modify construction processes (where possible) to reduce actual damage from the predicted levels, maintain building and infrastructure safety and functionality during construction and repair any residual damage on completion of the Project works. That is the intention of the SEMP.

- 71 It is envisaged that the approval of the Auckland Council will be required for any relevant revisions of a material nature to the Settlement Effects Management Plan – refer to Section 7 of that Plan.

Auckland City Council²⁷

- 72 The Auckland City Council (ACC) raises concerns about potential ground settlements affecting its closed landfill at Phyllis Street, and the potential effect of dewatering (from the approach ramp excavations) on the Alan Wood Reserve landfill materials.²⁸ The ACC is seeking further assessment of these issues, and the

²⁶ See section 3 (Monitoring), and Section 4 (Mitigation) of the SEMP, Appendix H to Technical Report G.13.

²⁷ Submitter No. 111.

²⁸ See paragraph 369 of Submission 111.

development of mitigation measures that take specific account of landfills.²⁹

- 73 I have discussed settlement of the Phyllis Street Reserve landfill in my response to the ARC submission above. While I consider that the calculated settlement of the landfill cap is unlikely to compromise its performance, I agree that a more detailed assessment should be carried out in the course of detailed design. Such an assessment would, of course, need to be reviewed and updated as part of the settlement monitoring and management programme. I expect mitigation measures to comprise surface regrading in areas where new surface water ponding occurs as a result of construction related settlement, as envisaged by Proposed Groundwater Condition G.7.³⁰
- 74 The situation in Alan Wood Reserve is similar, though I understand the extent of landfilling to be smaller and more localised than at Phyllis Street Reserve landfill. Differential ground settlement resulting from construction dewatering can be managed by regular inspection and mitigated by periodic re-levelling as it occurs.

Unitec Residential Flats at 1510 Great North Road³¹

- 75 These submitters express concerns about the potential for physical damage to the buildings on this property resulting from Project construction activities. This development is specifically addressed in Section 5.3.2.4 of Technical Report G.13. The larger of the buildings lies above the northbound tunnel, with some 20m of cover above the top of the tunnel excavation.³² Of this cover, between 10m and 18m is rock, and the remainder is weathered rock.
- 76 Figure E14 of Technical Report G.13³³ indicates estimated settlements of 20 to 50mm in this area. Figure G2 of Technical Report G.13³⁴ shows these buildings to lie outside the zone where greater than negligible building damage is predicted. The buildings do, however, have a mixed foundation system, comprising piles in some areas and shallow foundations elsewhere. This can increase susceptibility to damage from differential ground movements. For this reason, this development has been classed as Building Damage Category 2 – slight. Building Damage Category 2 is described as:³⁵

²⁹ See paragraph 370 of Submission 111.

³⁰ Attached to the evidence of Ms Williams.

³¹ Submitter Nos. 72, 98, 101, 106, 117, 125, 149, 160, 166, 181 and 240.

³² See AEE, Part F10, Sheet 326 (Northbound Alignment Geological Long Section Sheet 1 of 6).

³³ See **Annexure A** of my evidence.

³⁴ See **Annexure B** of my evidence.

³⁵ See Table 4.5 of Technical Report G.13.

"Cracks easily filled. Redecorating probably required. Several slight fractures showing inside of building. Cracks are visible externally and some repointing may be required externally to ensure weather tightness. Doors and windows may stick slightly."

- 77 The damage is expected to be non-structural and repairable.
- 78 It is proposed that these buildings be specifically monitored - refer Section 3.2 of the SEMP and proposed ground settlement conditions S.7 to S.13. That monitoring will comprise an initial condition survey, ongoing condition assessments during the active construction period, ground movement surveys, and a post-construction condition survey. If necessary, repairs will be undertaken as required to maintain the weather-tightness and habitability of the buildings during construction. The NZTA has undertaken to make good all construction related damage at the end of the construction period or such other time that depends on the owners' wishes and the degree of damage, and this is covered in amended proposed ground settlement condition S.12 (**Annexure D**).

Unitec Buildings³⁶

- 79 Unitec raises concerns about potential ground settlement effects on buildings on the western side of the Mt Albert campus, namely buildings 73, 77, 78, 79, 80, and buildings 310 to 313. These buildings are in the immediate vicinity of building 76, which because of its form of construction and height is specifically addressed in Technical Report G.13³⁷ and in the proposed conditions. The building damage assessment (**Annexure B**) indicates that these buildings lie in an area of Damage Category 0 – negligible. Proposed ground settlement conditions S.7 to S.13 propose that building 76 will be specifically assessed to monitor and mitigate possible building damage.
- 80 Buildings 73, 77, 78, 79, and 80 all lie within an area where more than 50mm settlement is estimated (**Annexure A**). Consequently, they will be subject to pre- and post-construction condition surveys in accordance with proposed ground settlement conditions S.7, S.8, S.12 and S.13, along with the wider scale settlement monitoring and updating of the damage assessment categories (and hence of monitoring approach) as appropriate. This will allow any construction related damage to be managed and mitigated.
- 81 Buildings 310 to 313 lie in an area where 25 to 50mm settlement is estimated (**Annexure A**). Consequently, condition assessments are not currently proposed.

³⁶ Submitter No.160, section 2.7.

³⁷ Section 3.2.4 of Technical Report G.13.

- 82 In my view this submission is addressed by the wider scale settlement monitoring and updating of the damage assessment categories for particular buildings that is proposed in the SEMP and in the Conditions.

Other Buildings and Issues (various submitters listed below)

- 83 A number of submitters express concern about the effects of ground settlement on their buildings or property. In some cases, submitters have identified localised areas where particular assessment will be required in the course of detailed investigation and design. Specific monitoring of ground movements and building or structure condition is warranted and (in many cases) already proposed in many of these locations, as part of the overall monitoring regime described in the SEMP.³⁸ It is also proposed in the settlement conditions.³⁹
- 84 I have inspected, from publically accessible vantage points, each of the submitters' properties in the course of preparing this evidence. In all cases, and while damage is not expected, the NZTA has undertaken to make good all construction related damage at the end of the construction period or such other time that depends on the owners' wishes and the degree of damage, and this is covered in amended proposed ground settlement condition S.12 (**Annexure D**). The various submitters are addressed in turn below:
- 85 *Submitter No.9: 3/1582 Great North Road* – seeking assurance that tunnel construction will not interfere with the structure or stability of the property. Figure G3 of Technical Report G.13 shows this property to lie outside the zone where greater than negligible building damage is predicted. It is within the area of settlement monitoring, so the damage assessment will be reviewed and updated as the Project proceeds, and appropriate specific monitoring and mitigation implemented.
- 86 *Submitter No.76: Pak'n Save New North Road* – requesting mitigation of settlement and remediation of any damage. This development is discussed specifically in Section 5.3.2.5 of Technical Report G 13, and is included in proposed ground settlement condition S.7. Pre-active construction, and post-construction inspections are proposed, and ground settlement will be monitored under the wider settlement monitoring regime.
- 87 *Submitter No.22 and No.90: 14 H and J Cradock St* – apparently part of a development constructed on unengineered fill, on the slopes above Oakley Creek. I recommend that specific investigation and a detailed site stability, ground movement and damage

³⁸ See section 3, pages 14-19 of SEMP, Appendix H of Technical Report G.13.

³⁹ See **Annexures C and D** to my evidence.

assessment be carried out for these (and the adjacent) properties in the course of detailed design, with monitoring and mitigation undertaken as appropriate. This is addressed in new proposed ground settlement condition S.16 (**Annexure D**).

- 88 *Submitter No.102: 34 Cradock St* – this property is also located close to Oakley Creek, and the submitter is concerned about slope stability. I recommend that this aspect is specifically investigated in the course of detailed design, with monitoring and mitigation undertaken as appropriate. This is addressed in new Proposed Ground Settlement Condition S.16 (**Annexure D**).
- 89 *Submitter No.118: 11 Hendon Avenue* – concerned about the possibility of settlement affecting the house. This property lies within the substrata designation so will be subject to a structural condition assessment before and following construction.⁴⁰
- 90 *Submitter Nos. 165 and 184: 26 Cradock St* – are concerned about the possibility of settlement affecting the house. This property lies within the substrata designation and in the zone where greater than 50mm settlement is estimated, so will be subject to structural condition assessment before and following construction.⁴¹ Refer Section 3.2 of the SEMP and proposed ground settlement conditions S.7, S.8, S.12 and S.13.
- 91 *Submitters Nos. 175 and 176: Waterview Primary School* – concerned about effects on the school swimming pool and hall, which are approximately 35m and 50m respectively from the northern tunnel cut and cover wall. Figure G2 of Technical Report G.13 (**Annexure B**) shows these structures to lie outside the zone where greater than negligible building damage is predicted. They are within the area of settlement monitoring, and, given their importance and, in the case of the swimming pool in particular, sensitivity to settlement, they have been included in the full structural assessment and monitoring programme.⁴²
- 92 *Submitter No. 179: Friends of Oakley Creek* – raises general concerns about the impact of ground settlement on Oakley Creek and the surrounding environment. It requests that the effects are further assessed and that the impacts be mitigated accordingly. The potential magnitude of settlement along Oakley Creek has been assessed in Technical Report G.13⁴³ and the freshwater ecological effects are described in Technical Report G.6. These Reports

⁴⁰ Refer Section 3.2 of the SEMP and proposed ground settlement conditions S.7, S.8, S.12 and S.13.

⁴¹ Ibid.

⁴² Refer **Annexure D**, amended proposed ground settlement conditions S.7 to S.13.

⁴³ Section 5.3.5 of Technical Report G.13.

conclude that the change in average stream velocity will be less than 0.1m/s, which is considered to be minor, so no significant effect on stream ecology is expected. Ground settlements will be re-assessed in the course of detailed design, and updated to reflect settlement monitoring results, so it will be possible to refine this assessment as the Project proceeds.

- 93 *Submitter No.215: 8 Waterview Downs* – concerned about proximity of the tunnel to the property and how the house may be affected. This property lies in Damage Category 2 – slight, and thus is one of the buildings identified in proposed condition S.7. It is plaster clad, and so falls in Type 1, brittle clad, as described in Section 3.2.2 of Technical Report G.13. Table 4.5 of Technical Report G.13 describes slight damage as:

"Cracks are easily filled. Redecorating probably required. Several slight fractures showing inside of building. Cracks are visible externally and some repointing may be required externally to ensure weather tightness. Doors and windows may stick slightly".

- 94 Proposed ground settlement conditions S.8 to S.13 describe the proposed approach to monitoring and mitigating possible building damage and this includes:

94.1 A pre-construction condition assessment;

94.2 Monthly visual inspections during active construction;

94.3 Monthly level and/or wall inclination surveys during active construction; and

94.4 A post-construction condition survey.

- 95 In my opinion, these measures, along with the wider-scale settlement monitoring and updating of the damage assessment categories for particular buildings, will allow any construction-related damage resulting from the Project to be managed and mitigated.

COMMENTS ON S149G REPORT BY THE ARC

- 96 In its s149G Report⁴⁴ to the Board, the ARC shares the conclusions reached in Technical Report G.13, that the effects from the estimated ground settlements caused by the tunnel construction are considered to be typically negligible, that monitoring should be carried out, and that mitigation measures are available. Section 2.7 of that Report identifies some groundwater queries, which may

⁴⁴ ARC Key Issues Report (October 2010), section 2.8.3.

affect the calculation of consolidation and hence total settlements. These queries are addressed in the evidence of Ms Ann Williams.

- 97 The proposed ground settlement conditions (**Annexure D**) and the Settlement Effects Management Plan require settlement estimates and the resulting building damage categories to be updated as detailed design work progresses, and through construction, as monitoring results are received and reviewed. In my opinion, this mechanism will allow any remaining aspects of the ARC groundwater queries (if any) to be resolved and the settlement estimates to be updated accordingly.
- 98 In my opinion, the programme of settlement, building condition and groundwater monitoring proposed in the attached ground settlement conditions, and in the SEMP addresses the ARC comment in Section 2.8.3 of its Report that *"monitoring should be carried out to confirm the above estimates, to quantify any actual damage and to allow for early warning of any areas where the remaining effects may be greater than predicted."*

PROPOSED GROUND SETTLEMENT CONDITIONS

- 99 In the documentation lodged with the AEE, the NZTA included a set of Proposed Consent Conditions (see Part E, Appendix E.1). This included proposed ground settlement conditions (attached to my evidence as **Annexure C**).
- 100 Following my review of the submissions received, I propose some amendments to those conditions which I recommend as appropriate. An amended version of those conditions is produced in full in **Annexure D** to my evidence.



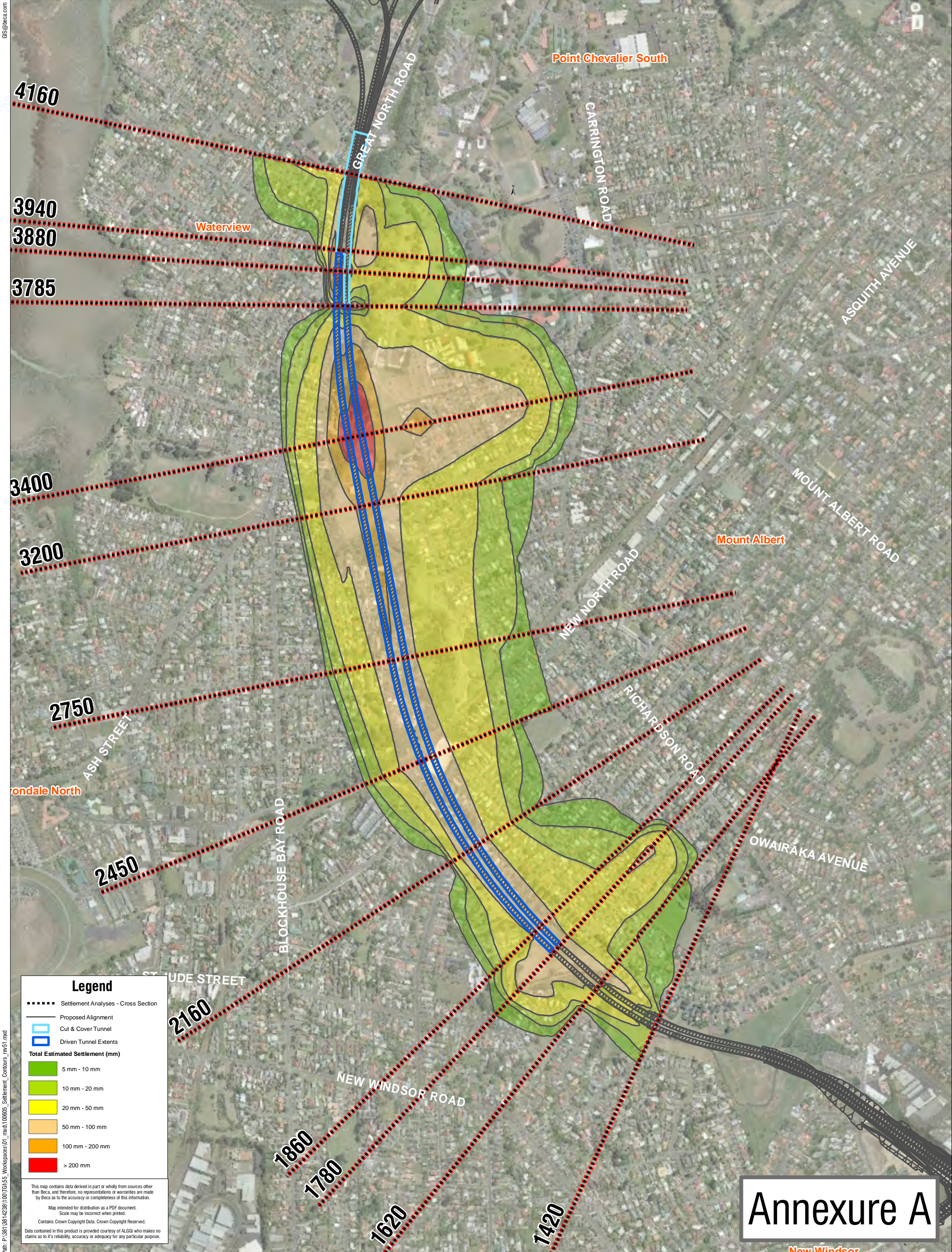
Gavin Alexander
November 2010

Annexures:

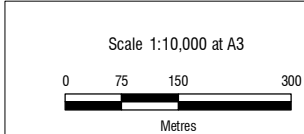
Annexure A	Total Estimated Settlement – Tunnel and Approaches
Annexure B	Settlement – Building Damage Categories
Annexure C	Proposed Ground Settlement Conditions (as lodged)
Annexure D	Amended Proposed Ground Settlement Conditions

**ANNEXURE A: TOTAL ESTIMATED GROUND SETTLEMENT – TUNNEL
AND APPROACHES⁴⁵**

⁴⁵ See Figure E14, Appendix E of Technical Report G.13.



Annexure A



Revision	By	Verified	Appd	Date
1	AYF	OK	AH4	05/05/10
2	CW3	OK	AH4	04/06/10
3	BAP	AF	AH	21/07/10

Title: **Waterview Connection Project- SH20**
Total Estimated Settlement - Tunnels & Approaches

Client: **NZ Transport Agency**

Project: **SH20 Waterview Connection Combined Surface Tunnel**

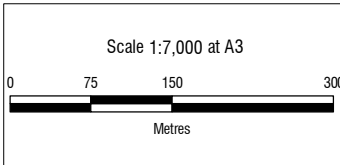
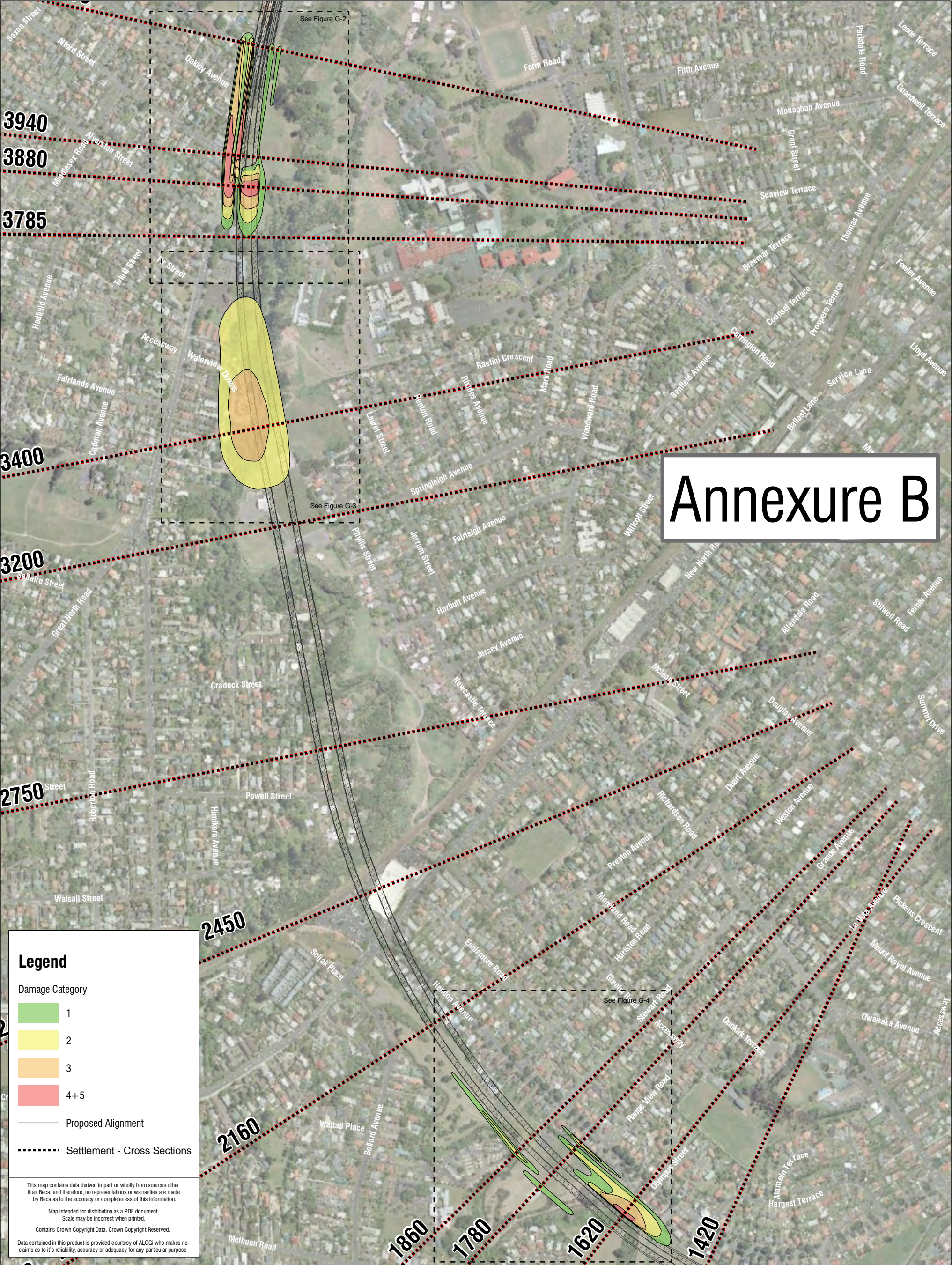


Discipline: **GIS**

Drawing No: **Figure E14**

ANNEXURE B: SETTLEMENT – BUILDING DAMAGE CATEGORIES⁴⁶

⁴⁶ See Figures G-1 to G-4, Appendix G of Technical Report G.13.



Revision	By	Verified	Appd	Date
Rev 01	BAP	AF	AH	21/07/10

Title:

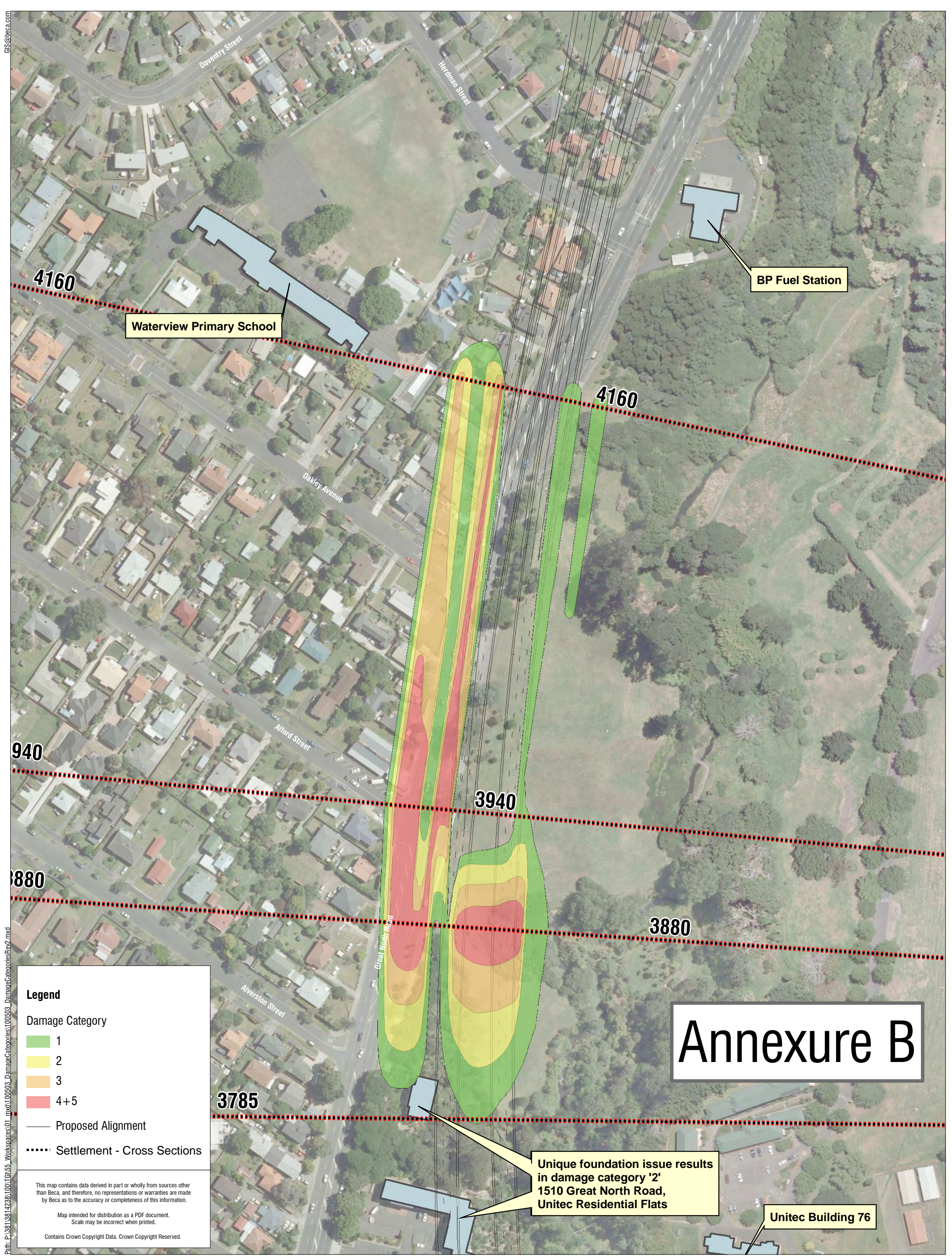
**Settlement - Building
Damage Categories**
[L = 10m, H = 3m]

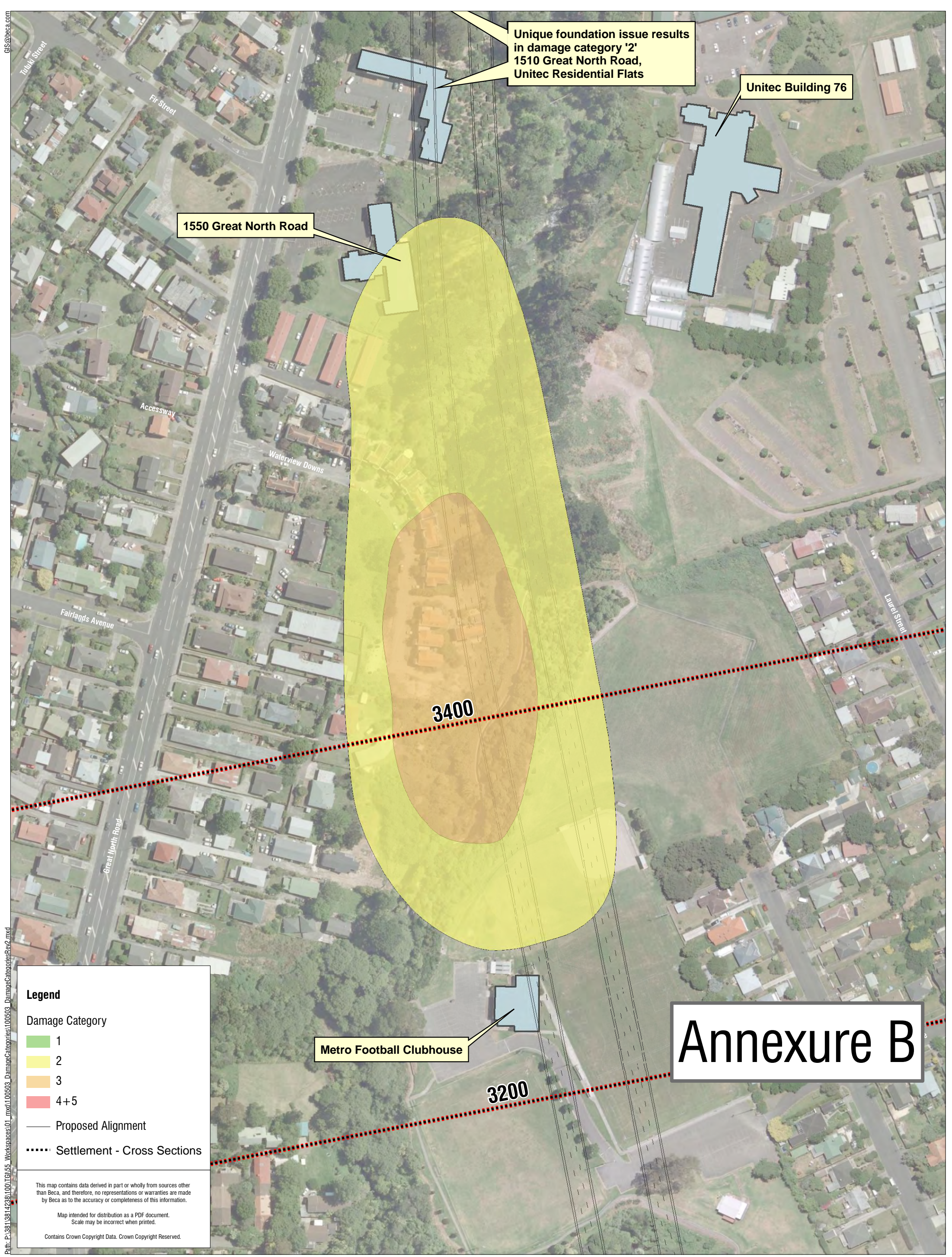
Figure: G - 1

Client:	New Zealand Transport Agency
Project:	SH20 Waterview Connection Combined Surface Tunnel



Discipline:	GIS
Drawing No:	GIS-3814238-28





Legend

Damage Category

- 1
- 2
- 3
- 4+5

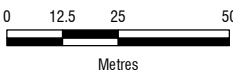
- Proposed Alignment
- Settlement - Cross Sections

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Revision	By	Verified	Appd	Date
Rev01	JYG	AYF	AH4	10/06/10
Rev2	BAP	AYF	AH4	21/07/10

Title:

**Settlement - Building
Damage Categories**
[L = 10m, H = 3m]

Figure: G - 3

Client:
New Zealand Transport Agency

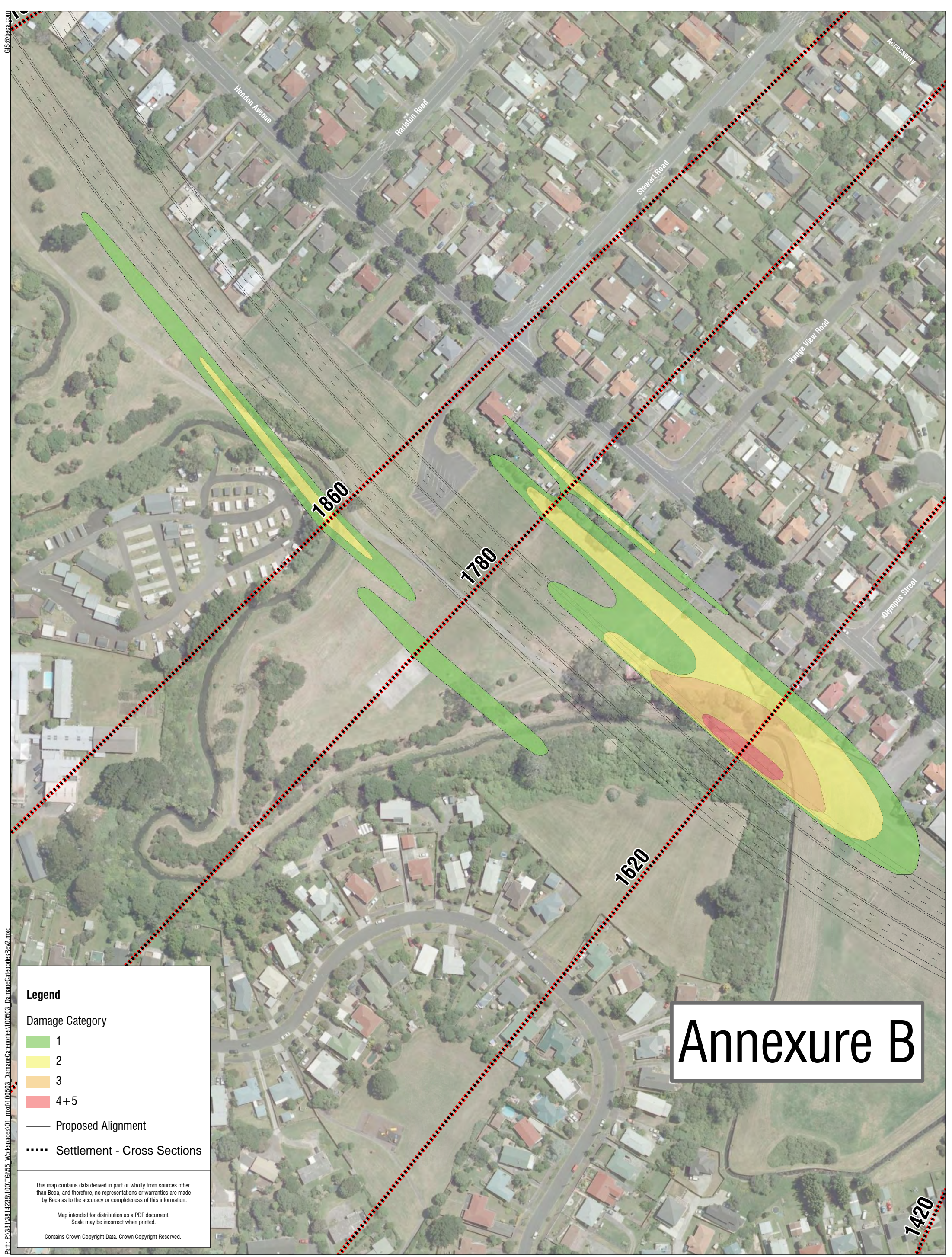
Project:
SH20 Waterview Connection
Combined Surface Tunnel



Beca

Discipline:
GIS

Drawing No:
GIS-3814238-18



Legend

Damage Category

- 1
- 2
- 3
- 4+5

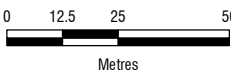
- Proposed Alignment
- Settlement - Cross Sections

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Revision	By	Verified	Appd	Date
Rev01	JYG	AYF	AH4	10/06/10
Rev2	BAP	AYF	AH4	21/07/10

Title:

**Settlement - Building
Damage Categories**
[L = 10m, H = 3m]

Figure: G - 4

Client:
New Zealand Transport Agency

Project:
SH20 Waterview Connection
Combined Surface Tunnel



Beca

Discipline:
GIS

Drawing No:
GIS-3814238-18

ANNEXURE C: PROPOSED GROUND SETTLEMENT CONDITIONS (AS LODGED)⁴⁷

S.1	The NZTA shall finalise, and implement through the CEMP, the Settlement Effects Management Plan (SEMP) lodged with the application prior to construction activities being undertaken and provide it to the [Auckland Council].
	Settlement Monitoring
S.2	<p>The NZTA shall establish a series of ground settlement monitoring markers to monitor potential settlement in relation to the construction of the tunnels. The survey markers will be located generally as follows:</p> <ul style="list-style-type: none"> (a) Along the tunnel alignment and extending out to a maximum of 400m either side of the tunnels to correlate with cross sections that have been used for the settlement estimates (b) To cover the more extensive eastern zone area of settlement at Chainage 3400 (Figure E.14 in Technical Report G.13 Assessment of Ground Settlement Effects) (c) On or around buildings or features considered to be particularly sensitive as defined in the SEMP. <p>Two types of markers shall be established: Framework Markers which shall form the main basis of monitoring, and Intermediate Markers which shall provide additional monitoring information. The locations of each type of settlement monitoring markers shall be confirmed in the SEMP.</p>
S.3	<p>The NZTA shall survey the settlement monitoring markers at the following frequency:</p> <ul style="list-style-type: none"> (a) Pre-construction <ul style="list-style-type: none"> i) All Framework Markers - Horizontal and vertical at 3 monthly intervals, starting at least 12 months prior to construction commencing; and ii) All Intermediate Markers - Horizontal and vertical once. (b) During Construction <ul style="list-style-type: none"> i) All Framework Markers - Vertical on a monthly basis; and ii) Selected Framework Markers only - Horizontal on a monthly basis. (c) During Active Construction <ul style="list-style-type: none"> i) All Framework and Intermediate Markers - Vertical on a weekly basis; and ii) Selected Framework Markers only - Horizontal on a monthly basis. <p>“Active construction” shall be defined as:</p> <ul style="list-style-type: none"> (a) Starting when the advancing tunnel face comes within 150m and ending when the final tunnel lining has been installed 150m beyond the section; and (b) When excavation in front of a retaining wall comes within 100m of a section and ending when the permanent wall supports are in place beyond a distance of 100m.

⁴⁷ AEE, Part E, Appendix E.1 at page 39.

S.4	Immediately following each monitoring round, the NZTA shall use the settlement monitoring results to reassess the building damage categories and compare them to those estimated in Technical Report G.13 <i>Assessment of Ground Settlement Effects</i> , submitted with this application. If the reassessment indicates that a building has increased its damage category from that in Technical Report G.13 <i>Assessment of Ground Settlement Effects</i> , then this shall be considered to be an Alarm Level and additional specific assessment of the building shall be carried out by the NZTA to confirm this reassessment within 72 hours. If the additional assessment confirms the increase in damage category, this shall be considered to be an Alert Level and the property owner and occupier will be notified within 48 hours. Following consultation with the property owner and occupier(s); subsequent actions may include increased frequency and/or extent of monitoring, modification to the construction approach or mitigation works to the affected building.
S.5	<p>The NZTA may reduce the frequency of settlement monitoring to 6 monthly:</p> <ul style="list-style-type: none"> (a) Once the active construction stage has passed; and (b) Monthly monitoring has been undertaken for a minimum of 6 months; and (c) The monitoring indicates that any potential settlement effects are within a satisfactory range as specified in the SEMP. <p>Settlement monitoring shall be undertaken for a period of 2 years following completion of the tunnels.</p>
S.6	The NZTA shall collate the results of the settlement monitoring (undertaken pursuant to Conditions S.2 – S.5) and prepare a report that shall be made available to the [Auckland Council]. A settlement monitoring report shall be prepared prior to the commencement of construction, and then at monthly intervals throughout the construction period. Following the completion of construction, a settlement monitoring report shall be prepared following each round of settlement monitoring undertaken (i.e. monthly and then 6 monthly when monitoring is reduced pursuant to Condition S.5).
	Building Condition Surveys
S.7	<p>The NZTA shall review and update the schedule of buildings and structures considered to be at risk in accordance with the criteria of the SEMP and maintain this for review by the [Auckland Council]. This shall include, but not be limited to, the following properties identified in the Technical Report G.13 <i>Assessment of Ground Settlement Effects</i> provided in support of this application:</p> <ul style="list-style-type: none"> (a) Buildings on properties within the substrata designation; (b) Buildings where total estimated settlement is greater than 50mm; (c) Buildings in areas estimated to have a risk of damage more than negligible; (d) Unitec Building 76; (e) 1510 Great South Road, Unitec Residential Flats (two buildings); (f) Pak'nSave Supermarket; (g) Metro Football Clubhouse, Phyllis Street; (h) Building at 1550 Great North Road; (i) BP Service station at 1380 Great North Road; (j) Modern Chairs Building (Richardson Road); and (k) Waterview Primary School.
S.8	The NZTA shall consult with owners of buildings and structures identified in Condition S.6 and, subject to the owner's approval of terms acceptable to the NZTA, shall undertake a pre-construction condition assessment of these structures in accordance with the SEMP.
S.9	The NZTA shall employ a suitably qualified person to undertake the building assessments required pursuant to Condition S.7 and identify this person in the SEMP.

S.10	<p>The NZTA shall undertake monthly visual inspections of the following buildings during the "active construction" phase of the Project as defined in Condition S.3:</p> <ul style="list-style-type: none"> (a) All Type 1 Dwellings within a zone where "more than negligible" effects have been predicted; (b) All Type 2 Dwellings within a zone where "slight" effects or greater have been predicted (c) Unitec Building 76; (d) 1510 Great North Road, Unitec Residential Flats (two buildings); (e) Pak n' Save supermarket. <p>Note: Type 1 and 2 Dwellings are those as defined in Technical Report G.13 <i>Assessment of Ground Settlement Effects</i>.</p>
S.11	<p>The NZTA shall undertake level and/or wall inclination surveys on a monthly basis during the "active construction" phase of the Project on the following buildings:</p> <ul style="list-style-type: none"> (a) All Type 1 Dwellings within a zone where "slight" effects or greater have been predicted; (b) Unitec Building 76; and (c) 1510 Great North Road, Unitec Residential Flats (two buildings)
S.12	<p>The NZTA shall, subject to the owner(s) approval, ensure that within 6 months of completion of construction activities a post-construction condition assessment covering the matters identified in the SEMP is undertaken. The assessment report shall include a determination of the cause of damage identified (if any) since the pre-construction condition assessments. The requirements of this condition need not be fulfilled for any particular building where the NZTA can provide reasonable evidence to the [Auckland Council] that the current owner of that building has agreed they do not require such a survey.</p>
S.13	<p>The NZTA shall ensure that a copy of the pre, post-construction and any additional building condition assessment reports for each building be forwarded to the respective property owner(s) within 15 working days of completing the reports. The NZTA shall notify the [Auckland Council] that the assessments have been completed.</p>
	Retaining Wall Monitoring
S.14	<p>The NZTA shall establish inclinometer and surface monitoring of the retaining walls for the tunnel portals and cut and cover tunnel to determine any potential effect from the tunnels. The nature and timing of the monitoring shall be determined during detailed design of the retaining walls and specified in the SEMP.</p>
	Services Monitoring
S.15	<p>Prior to construction commencing, the NZTA shall undertake CCTV surveys of services identified in the SEMP as being susceptible to damage or particularly critical. This shall include, but not be limited to:</p> <ul style="list-style-type: none"> (a) Waterview Orakei No.9 trunk sewer. <p>The NZTA shall undertake additional CCTV surveys throughout the construction period to ensure that there has been no significant damage to these services, and undertake remedial action as required in consultation with the service provider.</p>

ANNEXURE D: AMENDED PROPOSED GROUND SETTLEMENT CONDITIONS⁴⁸

S.1	<p>The NZTA shall finalise, and implement through the CEMP, the Settlement Effects Management Plan (SEMP) lodged with the application prior to construction activities being undertaken and provide it to the [Auckland Council]. <u>Prior to construction (following detailed investigation and design), the total estimated settlements and building damage categories shall be confirmed using the methodology adopted in the preparation of Technical Report G.13 and the SEMP shall be updated accordingly.</u></p>
	Settlement Monitoring
S.2	<p>The NZTA shall establish a series of ground settlement monitoring markers to monitor potential settlement in relation to the construction of the tunnels. The survey markers will be located generally as follows:</p> <ul style="list-style-type: none"> (a) Along the tunnel alignment and extending out to a maximum of 400m either side of the tunnels to correlate with cross sections that have been used for the settlement estimates <u>and to infill between them.</u> (b) To cover the more extensive eastern zone area of settlement at Chainage 3400 (Figure E.14 in Technical Report G.13 Assessment of Ground Settlement Effects) (c) On or around buildings or features considered to be particularly sensitive as defined in the SEMP <u>and as may be updated to reflect detailed analysis and interpretation of monitoring results as the project proceeds.</u> <p>Two types of markers shall be established: Framework Markers which shall form the main basis of monitoring, and Intermediate Markers which shall provide additional monitoring information. The locations of each type of settlement monitoring markers shall be confirmed in the SEMP.</p>
S.3	<p>The NZTA shall survey the settlement monitoring markers at the following frequency:</p> <ul style="list-style-type: none"> (a) Pre-construction <ul style="list-style-type: none"> i) All Framework Markers - Vertical <u>and selected</u> horizontal at 3 monthly intervals, starting at least 12 months prior to construction commencing; and ii) All Intermediate Markers - Vertical <u>and selected</u> horizontal once. (b) During Construction <ul style="list-style-type: none"> i) All Framework Markers - Vertical on a monthly basis; and ii) Selected Framework Markers only - Horizontal on a monthly basis. (c) During Active Construction <ul style="list-style-type: none"> i) All Framework and Intermediate Markers – Vertical on a weekly basis; and ii) Selected Framework Markers only - Horizontal on a monthly basis. <p>“Active construction” shall be defined as:</p> <ul style="list-style-type: none"> (a) Starting when the advancing tunnel face comes within 150m and ending when the final tunnel lining has been installed 150m beyond the section; and (b) When excavation in front of a retaining wall comes within 100m of a section and ending when the permanent wall supports are in place beyond a distance of 100m.

⁴⁸ Note: Underlined text has been inserted.

S.4	Immediately following each monitoring round, the NZTA shall use the settlement monitoring results (<u>together with the results of groundwater monitoring where they may provide an earlier indication of future settlements</u>) to reassess the <u>ground settlements and building damage categories</u> and compare them to those estimated in <u>the SEMP</u> . If the reassessment indicates that a building has increased its damage category from that in <u>the SEMP</u> , then this shall be considered to be an Alarm Level and additional specific assessment of the building shall be carried out by the NZTA to confirm this reassessment within 72 hours. If the additional assessment confirms the increase in damage category, this shall be considered to be an Alert Level and the property owner and occupier will be notified within 48 hours. Following consultation with the property owner and occupier(s); subsequent actions may include increased frequency and/or extent of monitoring, modification to the construction approach or mitigation works to the affected building.
S.5	<p>The NZTA may reduce the frequency of settlement monitoring to 6 monthly:</p> <ul style="list-style-type: none"> (a) Once the active construction stage has passed; and (b) Monthly monitoring has been undertaken for a minimum of 6 months; and (c) The monitoring indicates that any potential settlement effects are within a satisfactory range as specified in the SEMP. <p>Settlement monitoring shall be undertaken for a period of 2 years following completion of the tunnels.</p>
S.6	The NZTA shall collate the results of the settlement monitoring (undertaken pursuant to Conditions S.2 – S.5) and prepare a report that shall be made available to the [Auckland Council]. A settlement monitoring report shall be prepared prior to the commencement of construction, and then at monthly intervals throughout the construction period. Following the completion of construction, a settlement monitoring report shall be prepared following each round of settlement monitoring undertaken (i.e. monthly and then 6 monthly when monitoring is reduced pursuant to Condition S.5).
	Building Condition Surveys
S.7	<p>The NZTA shall review and update the schedule of buildings and structures considered to be at risk in accordance with the criteria of the SEMP and maintain this for review by the [Auckland Council]. This shall include, but not be limited to, the following properties identified in the Technical Report G.13 <i>Assessment of Ground Settlement Effects</i> provided in support of this application:</p> <ul style="list-style-type: none"> (a) Buildings on properties within the substrata designation; (b) Buildings where total estimated settlement is greater than 50mm; (c) Buildings in areas estimated to have a risk of damage more than negligible; (d) Unitec Building 76; (e) 1510 Great South Road, Unitec Residential Flats (two buildings); (f) Pak'nSave Supermarket; (g) Metro Football Clubhouse, Phyllis Street; (h) Building at 1550 Great North Road; (i) BP Service station at 1380 Great North Road; (j) Modern Chairs Building (Richardson Road); and (k) Waterview Primary School.
S.8	The NZTA shall consult with owners of buildings and structures identified in Condition S.7 and, subject to the owner's approval of terms acceptable to the NZTA, shall undertake a pre-construction condition assessment of these structures in accordance with the SEMP.
S.9	The NZTA shall employ a suitably qualified person (<u>eg a Chartered Professional Engineer</u>) to undertake the building assessments required pursuant to Condition S.7 and identify this person in the SEMP.

S.10	<p>The NZTA shall undertake monthly visual inspections of the following buildings during the "active construction" phase of the Project as defined in Condition S.3:</p> <ul style="list-style-type: none"> (a) All Type 1 Dwellings within a zone where "more than negligible" effects have been predicted; (b) All Type 2 Dwellings within a zone where "slight" effects or greater have been predicted (c) Unitec Building 76; (d) 1510 Great North Road, Unitec Residential Flats (two buildings); (e) Pak n' Save supermarket; <u>and</u> (f) <u>Waterview Primary School (pool and hall).</u> <p>Note: Type 1 and 2 Dwellings are those as defined in Technical Report G.13 <i>Assessment of Ground Settlement Effects</i>.</p>
S.11	<p>The NZTA shall undertake level and/or wall inclination surveys on a monthly basis during the "active construction" phase of the Project on the following buildings:</p> <ul style="list-style-type: none"> (a) All Type 1 Dwellings within a zone where "slight" effects or greater have been predicted; (b) Unitec Building 76; (c) 1510 Great North Road, Unitec Residential Flats (two buildings); <u>and</u> (d) <u>Waterview Primary School (pool).</u>
S.12	<p>The NZTA shall, subject to the owner(s) approval, ensure that within 6 months of completion of construction activities a post-construction condition assessment covering the matters identified in the SEMP is undertaken. The assessment report shall include a determination of the cause of damage identified (if any) since the pre-construction condition assessments. <u>The NZTA shall agree appropriate remedial works (if any) and arrangements for implementing them with the owner.</u> The requirements of this condition need not be fulfilled for any particular building where the NZTA can provide reasonable evidence to the [Auckland Council] that the current owner of that building has agreed they do not require such a survey.</p>
S.13	<p>The NZTA shall ensure that a copy of the pre, post-construction and any additional building condition assessment reports for each building be forwarded to the respective property owner(s) within 15 working days of completing the reports. The NZTA shall notify the [Auckland Council] that the assessments have been completed.</p>
	Retaining Wall Monitoring
S.14	<p>The NZTA shall establish inclinometer and surface monitoring of the retaining walls for the tunnel portals and cut and cover tunnel to determine any potential effect from the tunnels. The nature and timing of the monitoring shall be determined during detailed design of the retaining walls and specified in the SEMP.</p>

	Services Monitoring
S.15	<p>Prior to construction commencing, the NZTA shall undertake CCTV surveys of services identified in the SEMP as being susceptible to damage or particularly critical. This shall include, but not be limited to:</p> <p>(a) Waterview Orakei No.9 trunk sewer.</p> <p>The NZTA shall undertake additional CCTV surveys throughout the construction period to ensure that there has been no significant damage to these services, and undertake remedial action as required in consultation with the service provider.</p>
	<u>Slope Stability Assessments</u>
S.16	<p><u>Prior to construction commencing, the NZTA shall undertake geotechnical investigations of slopes or sites that have been identified as potentially being susceptible to movement. This shall include, but not be limited to:</u></p> <p>(a) <u>14H and 14J Cradock Street;</u></p> <p>(b) <u>34 Cradock Street;</u></p> <p>(c) <u>40 Cradock Street;</u></p> <p>(d) <u>56 Powell Street; and</u></p> <p>(e) <u>1590A Great North Road.</u></p> <p><u>The NZTA shall undertake monitoring throughout the active construction period in accordance with S.10 above and shall assess and agree remedial action as required in consultation with the owner in accordance with S.12 above.</u></p>