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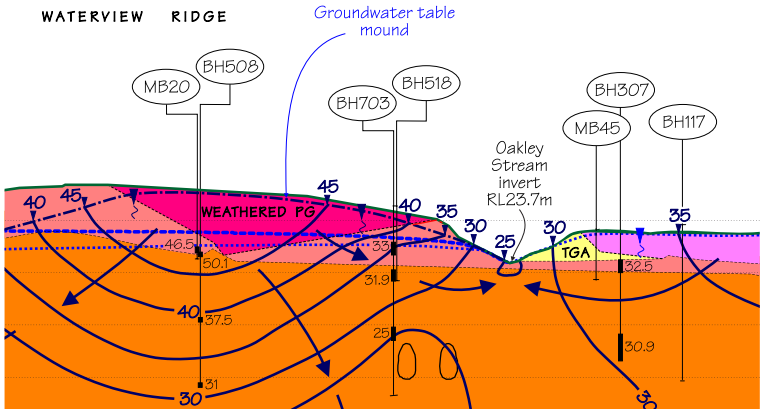
WATERVIEW CONNECTION

Auckland

Supplementary Section 42A Report

Groundwater and Settlement



DECEMBER 2010

Report prepared for:

ENVIRONMENTAL PROTECTION AGENCY

(Ministry for the Environment)

On behalf of:

WATERVIEW CONNECTION BOARD OF INQUIRY

Report prepared by:

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WATERVIEW CONNECTION

Auckland

Supplementary Section 42A Report
Groundwater and Settlement

EXECUTIVE SUMMARY

Earthtech have been engaged by the Environmental Protection Agency to prepare a Supplementary S42A Report relating to groundwater and settlement aspects of the Waterview Connection Project. This S42A Report is based on a review of:

- Lodged NZTA documents (August 2010).
- Post-lodgement NZTA reports.
- NZTA evidence.

Groundwater Effects

Comprehensive field investigations have been carried out to describe existing groundwater conditions. Earthtech agree with the hydrogeological units adopted and associated hydraulic conductivity and storage properties derived from testing.

The principal area of disagreement between NZTA and Earthtech relates to how perched and groundwater table conditions are defined. The Earthtech interpretation results in a more extensive groundwater table system that could be subject to tunnel construction effects.

NZTA has provided predictions of groundwater drawdown which are used for estimating settlement effects. The drawdown predictions are subject to uncertainty. The Earthtech review shows that drawdown related settlement could be greater in the vicinity of Waterview Ridge.

Settlement Effects

Best practice investigations, interpretation and analysis techniques have been used to assess the potential settlements arising from construction of the Waterview Connection Project (SH20 sectors).

Figure E14 provides the Applicant's best estimate predictions and this plan should be used as the base plan for the assessment of effects. This provides certainty to all parties.

Limited areas of adverse effects (building damage) are predicted, together with a clear undertaking by the Applicant to remediate or make good any adverse effects.

Settlement predictions over such a wide and diverse area cannot be precise and actual effects are likely to differ from the predictions. A comprehensive monitoring programme will provide field data prior to, during and after construction. The use of alert and alarm trigger values on groundwater levels, settlement markers and building evaluations should ensure that adverse effects are avoided wherever possible, and mitigated or remediated where damage is unavoidable.

The Applicant details an extensive list of practised mitigation measures that are available to reduce any adverse effects.

Conditions

NZTA draft consent conditions have been reviewed with main recommended changes highlighted. Further detail is expected to complete the conditions.

Recommendations

Groundwater drawdown is the principal factor in determining the magnitude and extent of settlement effects. If the Water Permits are granted, it is recommended that permitted total settlements be no greater than that shown on Figure E14 (Appendix A).

If monitoring during construction shows that settlement effects could be greater than the Figure E14 prediction then NZTA would need to undertake mitigation measures.

Limiting groundwater drawdown and settlement effects to that defined by Figure E14 provides certainty to the Waterview Connection Board and affected parties with respect to expected project effects.

WATERVIEW CONNECTION

Auckland

Supplementary Section 42A Report
Groundwater and Settlement

CONTENTS

Figures

Appendices

WATERVIEW CONNECTION

Auckland

Supplementary Section 42A Report
Groundwater and Settlement

1. REPORT BRIEF AND DOCUMENTS REVIEWED

Earthtech have been engaged by the Environmental Protection Agency (EPA) to assist the Waterview Connection Board by carrying out the following (21 December 2010 EPA Brief):

1. *Provision of a supplementary Section 42A report to the Waterview Connection Board of Inquiry in the expertise of hydrogeology/ground settlement to include the following:*

    a. *Review NZTA's Waterview Connection application material (as lodged) and evidence in chief, including any changes made to the application post-lodgement relevant to their specialisation.*
    b. *Identify any areas of disagreement with the applicant's evidence regarding the nature and/or magnitude of potential effects and /or proposed mitigation relevant to their specialisation.*
    c. *Review the proposed conditions and, if relevant, any management plan applicable to their specialisation included in the Assessment of Environmental Effects and NZTA's Evidence in Chief (Evidence of Amelia Linzey EIC No. 37) and comment.*

NZTA documents reviewed included the following:

i. Reports lodged with the EPA (20 August 2010 lodgement):

- Assessment of Groundwater Effects (AGE – Technical Report G.7).
- Assessment of Ground Settlement Effects (AGSE – Technical Report G.13).
- Geotechnical Interpretive Report (G.24).

ii. Post-lodgement reports:

- Assessment of Groundwater Effects, Addendum to Technical Report G7 (Ad. AGE – Appendix 4, Technical Report G.31).

iii. NZTA Evidence in Chief:

- Ann Williams – Groundwater
- Gavin Alexander – Ground Settlement
- Owen Burn – Consents
- Amelia Linzey – Conditions

2. SUMMARY OF PROJECT AND REVIEW AREAS

The Waterview Connection Project involves the construction of twin tunnels, portals, open highway and interchanges associated with SH16 and SH20 (Project Plan is attached in Appendix A).

This report reviews the SH20 groundwater and settlement effects associated with the tunnels, portals and highway approaches in Sectors 7, 8 and 9 of the Waterview Connection Project.

For the SH20 tunnels area, the AGE has investigated the following:

> *"Issues investigated that inform tunnel design include the:*
>
> - *Rate of inflow of groundwater to the tunnels, portals and excavations during construction and in the long term;*
> - *Uplift pressures beneath portal and tunnel floors, and groundwater pressures on tunnel lining; and*
> - *Efficacy of limiting these effects by wall and tunnel design elements and construction sequencing.*
>
> *Issues investigated that are important to understand because of their potential to impact on the environment include the:*
>
> - *Potential to cause groundwater drawdown that might result in ground settlement and affect existing structures;*
> - *Potential to affect Oakley Creek base flows and flow regime by altering groundwater flow in the vicinity of the tunnels, in particular during construction;*
> - *Potential to spread contaminants residing in areas of past landfilling by drawing groundwater down toward the tunnel excavations where they pass beneath such areas;*
> - *Potential to affect yield of quality of water at existing abstraction bores or springs by altering groundwater flow patterns; and*

- *Opportunities to mitigate potential environmental effects through design and construction sequencing."*

[Section 3.9 AGE]

In the associated settlement report, the AGSE has investigated the following:

> *"... the purpose of this report is to assess potential settlements associated with the SH20 section of the Project, the effects of these on the existing buildings, services and infrastructure and to propose monitoring and mitigation for those effects, where required."*
>
> *"This report describes the existing environment in which the effects are assessed to take place. This includes a review of the existing buildings in the area, the services, the transportation infrastructure and other features, where considered relevant.*
>
> *Settlement effects will result from several different aspects of the construction and operation. Each of these sources are described in the report, along with the methodologies for analysing and combining them. That data was then used to assess the effects on buildings, services, infrastructure and other relevant features. The report then presents the results of the assessment of settlement effects for each of these items.*
>
> *Finally, the report presents a proposed monitoring regime and potential mitigation measures. The monitoring regime will allow the actual magnitude of contributory causes, and of settlements and the resulting effects to be confirmed and compared with those predicted, while the mitigation provides particular measures should the monitoring indicate that these are required."*
>
> *[Section 2.2 Assessment of Ground Settlement Effects]*

This review relates to the hydrogeological and ground settlement aspects of the above.

3. ASSESSMENT OF GROUNDWATER EFFECTS

3.1 Assessment Methodology

The NZTA investigation objectives, general approach to groundwater modelling, consideration of construction staging and identification of potential drawdown effects (Sections 3 and 4 of AGE) are considered appropriate.

NZTA consider that groundwater drawdown is not an effect with the following evidence:

> *"48. I note that groundwater drawdown in itself is not an effect, but potential effects result from drawdown – such as pore pressure reduction that might result in ground settlement, or changes to groundwater flow and direction that might affect surface water or movement contaminants."*
>
> *[Ann Williams' Evidence in Chief]*

In terms of Section 3(a) to (f) of the RMA, groundwater drawdown is an effect and the above statement is not considered to be correct.

It is noted however, that potential adverse effects associated with groundwater drawdown have been appropriately described by the Applicant.

3.2 Existing Environment

3.2.1 Groundwater Investigations and Hydrogeological Units

The groundwater investigations have been carried out in association with the geotechnical investigations. These investigations are comprehensive and have consisted of a large number of boreholes, piezometer installation (180 standpipe and 51 vibrating wire peizometers), in-situ hydraulic conductivity (*k*) testing (171 slug tests and 7 x 7 day pump tests) and groundwater level monitoring (Section 5 of AGE). This fieldwork represents the most extensive groundwater investigations ever carried out for a project in the Auckland area.

The geological model proposed by NZTA with the description of seven hydrogeological units is accepted.

A detailed check of geology has been carried out for cross-section Ch2750*m* (see Appendix B). The check showed overall good agreement with the NZTA Ch2750*m* interpretation apart from a lower rock-head (top of East Coast Bays Formation (ECBF)) under the centre of Waterview Ridge. The lower rock-head position has been incorporated into the check groundwater modelling at Ch2750*m* (discussed in Section 3.3).

3.2.2 Groundwater Levels, Gradients and Direction of Flow

The groundwater monitoring network is considered sufficient for the understanding and assessment of existing groundwater systems and project effects. The interpretation of groundwater levels in terms of perched and groundwater table systems is addressed in the following Section 3.3.2.

3.2.3 Hydrogeological Properties

The hydraulic conductivity and storativity values as determined by the NZTA investigations presented in the AGE are accepted.

3.2.4 Groundwater Use

Existing groundwater use in the vicinity of the project is limited to five known bores and some springs. From the Addendum AGE, four of the bores have expired take consents.

On the basis of information provided drawdown effects on existing wells is not a significant effect.

The Auckland Volcanic Field (AVF) basalts and East Coast Bays Formation (ECBF) sandstones and siltstones both form locally extensive aquifers. In terms of existing use, these aquifers are currently under-allocated.

3.3 Effects Assessment – Groundwater Modelling

3.3.1 Overall Modelling Approach

The overall approach adopted by NZTA which uses 2D (SEEP/W) for local effects and 3D (MODFLOW) for distant effects is considered appropriate. The groundwater modelling has been carried out as follows:

i. Conceptual model development and the description of perched and groundwater table systems.
ii. Calibration of 2D and 3D numerical groundwater models to observed groundwater table levels.
iii. Prediction of groundwater effects using the 2D and 3D numerical groundwater models.

To carry out an independent review of the above, Earthtech have completed an independent check of Ch2750*m*, a critical cross-section associated with the tunnel. The Earthtech check of Ch2750*m* is attached as Appendix B.

3.3.2 Conceptual Groundwater Model

- *Perched and Groundwater Table Systems*

NZTA provides the following broad description of site groundwater systems:

> *"51. Groundwater levels within the ECBF and Parnell Grit are similar to the water level in Oakley Creek and indicate a northerly gradient of 3% to 4% falling to close to sea-level at the coast, with a small local component of flow toward Oakley Creek. These water levels are considered to represent the regional groundwater system, which is semi-confined.*
>
> *52. Water levels in the basalt, Tauranga Group and weathered ECBF and weathered Parnell Grit respond directly to rainfall events and represent perched water levels that exist because of the contrast in permeability between these units. That is, water resides in higher permeability layers (such as the basalt or sand lenses within the Tauranga Group) and is 'hung up' on top of lower permeability layers. Water 'leaks' more slowly through these lower permeability layers, which can be described as aquitards because they slow the rate of groundwater flow."*
>
> *[Ann Williams' Evidence in Chief]*

The principal area of disagreement between NZTA and Earthtech relates to how the perched and groundwater table conditions are defined.

Figure 3.1 shows a typical text book definition of perched groundwater. This conceptualisation has been further developed in Figure 3.2.

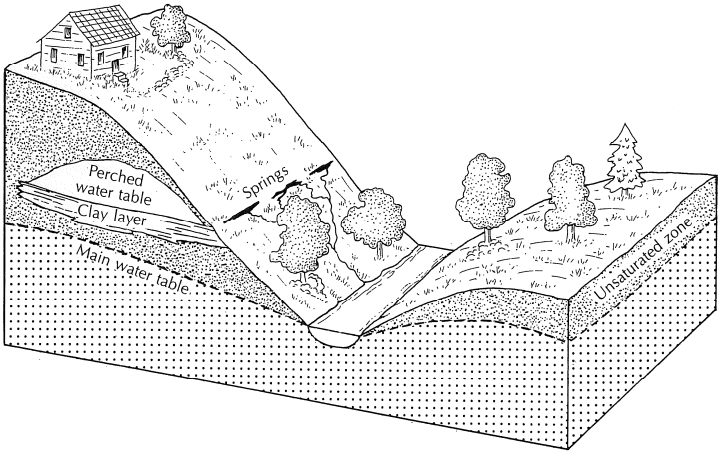


Figure 3.1 – Perched Aquifer
Perched aquifer formed above the main water table on a
low permeability layer in the unsaturated zone. [Fetter, 1994]

On the basis of Figure 3.2, the following groundwater conditions are expected:

i. *Upper Perched System*

- Series of isolated groundwater bodies with limited (water) pressure heads.
- Separated from groundwater table system by zones of partially saturated ground.

ii. *Lower Groundwater Table System*

- Extensive groundwater body fully saturated below the groundwater table.
- Fully saturated conditions defined by overlapping pressure heads in nested piezometers.
- Increasing pressure heads with depth.

The above definitions have been adopted by Earthtech for other Auckland groundwater projects including the North Waikato Regional Landfill where both 2D (Earthtech, 1999) and 3D (by Pattle Delamore Partners) groundwater modelling was carried out in similar geology to the Waterview Connection Project.

Post-lodgement, NZTA provided (Addendum AGE) additional interpretation of the perched groundwater systems which is summarised in the following evidence:

> *"74. In the project area, a cascading series of perched water tables is recorded within the Waitemata Group soils and rocks, as occurs throughout the Waitemata Group rocks in the Auckland Region. Infiltrating groundwater is held up on lower permeability layers, slowly discharging through fractures and the rock mass to the underlying higher permeability layers until again being "caught" above a further low permeability layer.*
>
> *75. The head of water on each successive water table is only a fraction of the total head between the regional (lowest recorded) water table and the uppermost (near surface) water table. This is the case even where the hydrostatic levels in successive groundwater lenses overlap. This means that when deep excavations are made in Waitemata Group rock, these local perched water tables discharge without inducing wider ground settlement. (Examples I am familiar with include the 23m deep Sky City excavation, the 8m deep New Lynn Rail Trench excavation and the Maioro Street interchange, which is itself a part of the Richardson Road ridge.)"*
>
> *[Ann Williams' Evidence in Chief]*

NZTA consider areas showing overlapping pressure heads with depth to be perched groundwater systems. Earthtech disagree with this interpretation and consider that these areas represent fully saturated ground below the groundwater table.

The Earthtech interpretation results in a more extensive groundwater table system subject to tunnel construction effects. This leads to groundwater drawdown effects extending over a larger area with the potential to cause increased settlement to that predicted by NZTA.

The differences in the NZTA and Earthtech interpretations also influences the interpretation of groundwater monitoring during construction.

- *Conceptual Modelling*

  Figure B2 (Appendix B) shows a groundwater flow net associated with the Earthtech Ch2750*m* check section. The flow net is based on pressure head plots (Figure B1) and measured groundwater levels in monitoring piezometers. The conceptual model shows the following:

  i. Limited extent of perched groundwater.
  ii. Significant mounding of the groundwater table under Waterview Ridge.

  Groundwater table positions are also plotted on Figure B2 from the NZTA Ch2750*m* modelling (AGE and Addendum AGE). These groundwater table positions demonstrate the significant differences between the conceptual models adopted by NZTA and Earthtech under Waterview Ridge.

3.3.3 Model Calibration

The Earthtech Ch2750*m* check model was calibrated by adjusting k_v (vertical hydraulic conductivity) and rainfall recharge within a plausible range until a match was achieved between observed and calculated heads. This calibrated model incorporates a groundwater table mound under Waterview Ridge and model settings based on site and published information.

Figure B3 shows the Earthtech and NZTA calibrated models for Ch2750*m*. In terms of the central Waterview Ridge area, the differences are as follows:

Ch2750*m* 2D Model	**Groundwater Table Level**
i. NZTA (AGE)	RL32 to 34*m*
ii. Earthtech	RL42 to 45*m*

The 2D NZTA modelling only shows limited mounding of the groundwater table under Waterview Ridge and is not considered to be adequately calibrated.

The NZTA 3D calibrated groundwater table is presented on Figure F4b in the AGE. Under the central portions of the Waterview Ridge at Ch2750*m* the 3D calibrated groundwater table level is at RL25 to 30*m*,

significantly below the RL42 to 45*m* from the Earthtech check model. The NZT 3D groundwater model is also not considered to be adequately calibrated under the Waterview Ridge area.

3.3.4 Prediction of Drawdown Settlement Effects

The groundwater table mound under Waterview Ridge incorporates a greater extent of potentially compressible soils (WPG and WECBF) to that assessed by NZTA. Therefore a greater extent and increased settlement magnitudes are considered possible based on the Ch2750*m* check model.

The increased settlement predicted is demonstrated in the Addendum AGE where predicted total settlements increased by 26% for an initial groundwater table approximately 5*m* higher than that modelled at Ch2750*m* in the AGE (see Figure B3).

3.3.5 Drawdown Prediction Uncertainty

A principal aim of groundwater investigations associated with major excavation projects is to provide moderately conservative drawdown predictions. However, these predictions are not always correct. Monitoring for groundwater responses to consented dewatering projects in the Auckland area has found the following:

i. *Drawdown effects less than predicted.*

- Ihumatao Quarry Dewatering, Mangere (34*m* drawdown – ET, 2010).

ii. *Drawdown effects close to predicted.*

- Britomart Transport Centre, Auckland CBD. (Basement excavation to 9.5*m* below groundwater table – Namjou and Pattle, 2006).

iii. *Drawdown effects greater than predicted.*

- Three Kings Quarry Dewatering, Auckland. (24*m* drawdown – Harding *et.al*, 2010).

On the basis of the above, uncertainty needs to be considered when assessing groundwater drawdown effects.

3.3.6 Groundwater Effects Conclusion

NZTA has provided predictions of groundwater drawdown which are used for estimating settlement effects. The drawdown predictions are subject to uncertainty. The Earthtech review shows that drawdown related settlement could be greater in the vicinity of Waterview Ridge.

Groundwater drawdown is the principal factor in determining the magnitude and extent of settlement effects. If the Water Permits are granted, it is recommended that permitted total settlements be no greater to that shown on Figure E14 (Appendix A).

If monitoring during construction shows that settlement effects could be greater than the Figure E14 prediction then NZTA would need to undertake mitigation measures (Section 5).

Limited groundwater drawdown and settlement effects to that defined by Figure E14 provides certainty to the Waterview Connection Board and affected parties with respect to expected project effects.

4. ASSESSMENT OF SETTLEMENT EFFECTS

4.1 Methodology

The Application evidence and supporting reports provide a detailed evaluation of the potential magnitude and effects of ground settlements arising from the construction and operation of the proposed SH20 tunnels and retaining wall structures at either end of the tunnels.

Settlements are generated by three separate sources and superimposed to provide an overall potential settlement profile. The three sources identified are:

1. Mechanical settlement of the ground due to construction of the tunnels.
2. Mechanical settlement of the ground due to construction of retaining walls.
3. Consolidation of the ground due to extraction of groundwater as a result of tunnelling and/or excavation operations.

The settlement effects reports draw on two related reports which describe the geotechnical conditions (report G24 by Tonkin and Taylor) and the groundwater drawdown predictions (report G7 by Beca).

Development of a 3D geological model provides an indication of the anticipated soil and rock conditions along the tunnel route and within a distance of up to 600*m* either side. This model has been derived from mapping and a large number of site specific investigations which include boreholes up to 60*m* deep.

In-situ testing (SPT-N tests, cone penetrometers tests and dilatometer tests) has been combined with laboratory testing to provide engineering properties of the various soil types along the route. These engineering properties have then been used in conjunction with standard practise geotechnical formulae and computer models to predict both vertical and horizontal displacements arising from the works. The change in groundwater pressures is the driving force for the consolidation related settlements.

The settlement predictions have been analysed for 13 cross-sections and then compiled onto a plan which has been overlaid on an aerial photograph on Figure E14 (attached in Appendix A) to provide a clear summary of the extent of the predicted effects. The area is zoned into different categories relating to total settlements of:

5 to 10*mm* settlement
10 to 20*mm* settlement
20 to 50*mm* settlement
50 to 100*mm* settlement
100 to 200*mm* settlement
>200*mm* settlement

These predictions are considered conservative and so should not be exceeded at any stage of the works.

Figure E14 is truncated at the northern and southern end of the works (Ch4160and Ch1420*m* respectively). Drawdown and settlement effects may extend beyond these limits and Figure E14 should be adjusted accordingly.

The Application also describes the types of buildings, services and other features in the zone of influence that could potentially be affected by these settlements.

The Application stresses the importance of the difference between total settlements and differential settlements in regard to their effects on different types of buildings and services, e.g. it is quite possible for a building to settle a total of 200*mm* and suffer no damage or adverse effects, but the same building could be cracked by a differential settlement of only 20*mm*. The opposite effect could occur with a sewer line where the total settlement of 200*mm* may result in a loss

of gradient (and hence flow capacity) and the 20*mm* differential could be easily accommodated by a flexible pipeline.

The Application provides adequate details of the types of buildings and services within the predicted settlement zone. This information has then been analysed with the total and differential settlement predictions and the Building Assessment Categories defined in Table 4.5 with Category 1 being very slight cracks to Category 5 being very severe and probably requiring demolition rather than repair.

Table 4.5
Building/Structure Damage Category (after Burland, 1997)

Damage Category	Category of Damage	Description of Typical Damage (Ease of Repair is Underlined)	Approx Crack Width (*mm*)	Limited Tensile Strain (%)
0	Negligible	Hairline cracks.	<0.1	<0.05
1	Very Slight	Fine cracks that can be easily treated during normal decoration. Perhaps isolated slight fracture in buildings. Cracks in external brickwork visible on inspection.	<1	0.05 to 0.075
2	Slight	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.	<5	0.75 to 0.15
3	Moderate	The cracks require some opening up and can be patched by a mason. Recurrent cracks can be masked by suitable linings. Repointing of external brickwork to be replaced. Doors and windows sticking. Service pipes may fracture. Weather tightness often impaired.	5 to 15 or a number of cracks >3	0.15 to 0.3
4	Severe	Extensive repair work involving breaking out and replacing sections of walls, especially over doors and windows. Windows and door frames distorted, floor sloping noticeably. Walls leaning and bulging noticeably, some loss of bearing in beams. Service pipes disrupted.	15 to 25 but also depends on number of cracks	>0.3
5	Very Severe	This requires a major repair job involving partial or complete rebuilding. Beams lose bearing, walls lean badly and requiring shoring. Windows broken due to distortion. Danger of instability.	Usually >25 but depends on number of cracks	

Table Notes:

- In assessing the degree of damage, account must be taken of its location in the building or structure.
- Crack width is only one aspect of damage and should not be used on its own as a direct measure.
- The table is based on buildings of brick/blockwork masonry construction.

These building categories have in turn been overlaid on site plans to show where the tunnelling and/or excavation works could result in building damage. These plans are provided in Figures G1, G2 and G3 (attached in Appendix A). These provide the best assessment of areas where possible building damage may occur.

The Application recognises the difficulties in making reliable and accurate building damage predictions via a large number of assumptions and generalisations that are necessary to develop the geological, groundwater and settlement prediction models. As a result of this uncertainty, an extensive monitoring programme is planned. This will monitor groundwater drawdowns, actual settlements, actual building movements and survey for damage at key locations to ensure that the physical works do not cause more damage than predicted. The monitoring data will be continuously updated and reviewed with the aim of avoiding damage wherever possible.

Mitigation measures are available to reduce the effects of all three types of settlement. If these are not effective and damage does occur, the Applicant undertakes to repair all damage or reinstate to the satisfaction of the owner.

4.2 Areas of Concern

Two areas of concern have arisen from this review:

- The effects of local conditions on ground settlements; and
- The effect of settlement on the existing, marginally stable Oakley Creek banks.

4.2.1 Ground Variability on a Small Scale

The existing environment is comprehensively described in general terms in the various reports. The scale of the project is such that it is difficult to describe conditions adequately on a local scale – other than where specific items have been highlighted, e.g. the three landfill site and the Unitec buildings. Hence the reports and calculations rely on global or smoothed data for the settlement predictions.

The use of global parameters for the soil and rock types has led to "average" strength parameters with sensitivity considered by using a range or lower bound values. Only when considering individual properties is the variability in ground conditions over short distances exposed, e.g. 40 Cradock Street is located on or adjacent to uncontrolled fill over steep slopes above Oakley Creek while the adjacent property is located on a flat terrace area. Both lie in a predicted 50 to 100*mm* settlement zone but the effects may be significantly different.

4.2.2 Slope Stability of the Oakley Creek Banks

The project covers a diverse area of natural conditions which have been extensively modified by urbanisation. Key features of the natural environment include the location of Oakley Creek as a result of preferential erosion around the edge of the Mt Albert basalt flows. Down cutting by the creek has left an unstable creek bank environment which by default, rather than by design, was not urbanised and has only recently been recognised as an important and has only recently been recognised as an important urban reserve. This "gap" in urbanisation now defines the location of the tunnels in order to avoid, as far as possible, tunnelling beneath private or commercial properties.

Encroachment of urbanisation either side of the creek has led to channelling, quarrying, landfilling and fly-tipping alongside the creek. More recently, as the reserve land has been improved and developed, houses have been constructed on the creek banks. Many of these house have required cut and fill earthworks, retaining walls and specific foundation designs to safely build on the naturally unstable banks.

The effects of the predicted tunnel related settlements on these slopes have not been addressed in any of the site visits, reports or evidence reviewed to date – other than the inclusion of condition S.16 attached to G. Alexander's evidence. This condition calls for slope stability assessments of six properties located on the western side of Oakley Creek (in Craddock Street, Powell Street and Great North Road).

A brief inspection of the area on 22 December 2010 by Earthtech indicated a large number of dwellings which have been built on these "over-steepened slopes" and many more could have the same concerns as those listed under condition S.16.

The site inspection of both sides of the creek between Ch2750 and Ch3400*m* revealed:

- Steep, unstable slopes retained with pole walls, gabions and rock buttress fills.
- Steep, uncontrolled fill slopes where random fill has been pushed over the edge and subsequently developed as residential lots.
- Irregular settlement and/or slope instability damage of the concrete walkway paths.
- Existing creek erosion problems.

The effects of ground settlement and groundwater drawdown on both sides of Oakley Creek have not been addressed in regard to existing and future stability and existing slope movement damage.

4.3 Assessment of Effects by the Applicant

The conclusions of the Application reports are as follows:

- *The effects from the estimated ground settlements caused by the tunnel construction are considered to be typically negligible with some isolated areas of very slight to slight damage predicted.*
- *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 resulting effects may be greater than predicted.*
- *Mitigation measures are easily available for the predicted levels of damage and for the low likelihood that greater effects do occur.*

4.4 Assessment of Effects by the Reviewer

Predicting settlements in variable ground conditions over varying depths and topographical areas is clearly not an exact science. The Applicant has used the best available investigations, testing and analytical techniques to make what is considered a conservative estimate of the potential effects. The models will change as more information becomes available through the detailed design process, the initial monitoring programme and as a result of unforeseen effects during construction itself. The groundwater model is open to different interpretations. The settlement models are largely controlled by the geotechnical strength parameters which have been derived from a wide range of samples. The models have not been checked for site specific conditions but relate to global

values for each soil and rock type. Differences at geological boundaries in particular are difficult to model and will lead to anomalies between the settlement predictions and the settlement measurements. Buildings themselves respond to the ground settlements in different ways. The monitoring process is complicated by seasonal and weather related effects, the selection of practical monitoring points, access, owners permission, survey accuracy and building damage assessment accuracy.

Notwithstanding all of the above, the Application is based on best practise techniques, tunnels have been driven in Auckland in similar conditions without causing unforeseen adverse effects and there is no reason why this project cannot be completed within the bounds of the limited damage categories predicted.

A specific assessment of the effects of settlement on stability of the Oakley Creek banks is required.

5. MITIGATION OPTIONS

Appropriate trigger levels need to be set to define when mitigation measures should be implemented. In most cases, an early response is likely to avoid or reduce the damage. In some cases where damage is very slight, a delayed response (e.g. redecorating) is appropriate.

The following mitigation options are proposed by NZTA:

5.1 Groundwater Mitigation

Possible groundwater mitigation measures include the following (Section 7 of AGE and Paragraph 60 of Ann Williams' evidence):

i. Grouting.
ii. Shorter construction to lining timeframes.
iii. Artificial recharge of ECBF using deep injection wells.

The above mitigation options are considered feasible and appropriate for the project.

5.2 Settlement Mitigation

Settlement mitigation measures include:

i. Mechanical Settlements – additional anchors, props, temporary supports, drainage measures, removal of wall surcharges, grouting ahead of tunnelling, rock bolts.

ii. Consolidation Settlements – grout curtains, short-term re-injection, grout stabilisation works, tunnel lining modifications.

5.3 Building Mitigation

Building mitigation measures include:

i. Non-Structural Effects – repointing of brick work, repainting and redecorating.

ii. Structural Effects – detailed evaluation by Structural Engineer and local repair or rebuilding of sections affected. Underpinning and/or re-levelling.

5.4 Services Mitigation

Services mitigation measures include:

i. Crack repairs, relining of pipes, additional supports, diversion via adjacent services, replacement.

6. CONDITIONS

6.1 Water Permits

NZTA are applying for the following Water Permits (from Table 3, Owen Burn – First Statement Evidence in Chief).

EPA Ref No.	Consents	Comments
EPA 10/2.027 (ARC: 38321)	Taking and Use of Groundwater	The taking of groundwater for the purposes of groundwater diversion during construction, under Rule 6.5.69. Sectors 7 to 8.
EPA 10/2.027 (ARC: 38321)	Taking and Use of Groundwater	The taking of groundwater for the purposes of groundwater diversion – operation, under Rule 6.5.69. Sectors 7 to 8.
EPA 10/2.028 (ARC: 38322)	Diversion of Groundwater	Diversion of Groundwater for the tunnel (taking of groundwater for disposal). Relates to Sectors 7 and 8.

6.2 Comments on Groundwater Conditions

Earthtech have reviewed and are in general agreement with the amended proposed groundwater conditions presented in Annexure D of Ann Williams' Evidence in Chief.

The following revisions to the NZTA conditions are recommended to provide adequate controls for the Water Permits applied for:

6.2.1 Groundwater Take Volumes

Groundwater take volumes need to be specified in the consent conditions. This provides control of construction dewatering volumes and allows long term management of the AVF and ECBF aquifers in terms of future groundwater availability.

The recommended take volumes are as follows (based on Table 8.1 of AGE and paragraphs 56, 60 and 63 of Ann Williams' Evidence in Chief):

i. *Northern Portals and Approaches – 400m Length*

- Construction Inflows
  $Q = 800m^3/d$

- Long Term Inflows (fully drained construction option)
  $Q = 280m^3/d = 102{,}200m^3/yr$

ii. *Tunnels – 2500m Length*

- Construction Inflows

ECBF	2,250*m* at 5$m^3/d/m$	11,250m^3/d
PG	250*m* at 120$m^3/d/m$	30,000m^3/d
		41,250m^3/d

- Long Term Inflows (fully sealed construction option)
  2,500*m* at 0.07$m^3/d/m$ = 175m^3/d = 63,875m^3/yr,
  say 63,900m^3/yr

iii. *Southern Portal and Approaches – 450m Length*

- Construction Inflows

Basalt	150*m* at 75$m^3/d/m$	11,250m^3/d
Remainder	300*m* at 1.7$m^3/d/m$	510m^3/d
		11,760m^3/d

- Long Term Inflows (fully drained construction option)
  450*m* at 0.5$m^3/d/m$ = 225m^3/d = 82,125m^3/yr,
  say 82,100m^3/yr

6.2.3 Tunnel and Approach Alignment

The AGE and AGSE are based on a horizontal and vertical alignment currently preferred by NZTA. If the tunnel is constructed on a different alignment greater effects than predicted could occur.

A new condition G10 is recommended fixing the design alignment to the preferred position assessed by the AGE and AGSE.

6.2.4 Groundwater Management Plan

The GWMP relates to the tunnels, portals and approaches. The GWMP needs to be prepared prior to project construction dewatering.

It is also recommended that the GWMP is submitted to the Auckland Council prior to the commencement of construction dewatering.

Condition G1 has been revised accordingly.

6.2.5 Phyllis Street Landfill Monitoring

Monitoring of wells within the landfill is proposed in Condition G7.

It is recommended that monitoring bores located between the base of the landfill and the tunnel alignment also be monitored for leachate indicators (pH, conductivity, chloride, ammonium and boron). The groundwater quality monitoring should take place at three monthly intervals when tunnel construction is within 100*m* of the landfill and continue until permanent tunnel lining is constructed.

6.3 Comments on Proposed Settlement Conditions

The settlement effects conditions lodged with the Application have been amended by Mr Gavin Alexander (Beca) following his review of the submissions received. Notifications to these amended conditions (Annexure D of G. Alexander evidence) are attached with explanations as follows:

Condition No. S.1

Mr Alexander's amended condition requires an updated version of the settlement prediction (Figure E14) and the building damage categories (Sheets G1, G2 and G3) prior to construction. The outcome of this update is not certain and may lead to an increase or decrease in the effects. This leaves affected parties and the Hearing Committee with no certainty that the effects will be no more than currently predicted. Adding the following paragraph to S.1 provides more certainty.

> "In the event that settlement predictions are greater (than E14) or building damage categories increase in ranking or number of buildings, mitigation measures shall be introduced as part of the detailed design and construction process to avoid any adverse effects greater than predicted by the Application lodged in August 2010."

Condition No. S.2(a)

The final sentence requires field monitoring of differential settlements. This can only be done in practise by having closely spaced monitoring pins (20*m* maximum spacing suggested). If monitoring pins are simply placed at say 50*m* centres they do not record differential movements on a scale which could affect individual buildings.

Condition No. S.2

The final paragraph has been added to provide alert and alarm levels based on Figure E14. This provides all parties with confidence that any changes to the predictions on E14 will be noted and dealt with appropriately. The alert level suggested is 75% of the E14 levels with the alarm level at 100% of the E14 levels.

Condition No. 5.4

This is an extraordinary complicated condition that is unlikely to be workable in setting effective alert and alarm levels and initiating appropriate responses. The condition requires:

- Collection and interpretation of groundwater data.
- Collection and interpretation of settlement data.
- Reassessment of Figures E14 and G1, G2 and G3.
- Alarm triggered only if a building has increased its damage category from that in the SEMP (i.e. alarms can only be triggered by specific buildings).
- Alert triggered only if reassessment of the building confirms the increase in building damage category.

At best, this condition will take four to seven days to obtain an interpretation after receipt of the settlement data. At worst, settlement effects could be faithfully recorded but no action is taken as the affected property is not in the initial building assessment list.

Suggest delete and replace with S.4 as described below.

> "This condition relates to S.2 and the need to also set trigger levels for the differential settlement monitoring markers. The alert level proposed is 1 in 1000 with an alarm level at 1 in 500. Building damage generally does not occur until differential settlements exceed approximately 1 in 400 (25*mm* over a 10*m* building dimension)."

Condition No. S.6

A number of projects have collected monitoring data but no attempt has been made to interpret the effects – simply collating and reporting the data is not adequate.

Add the following:

> "The settlement reports shall highlight any alert or alarm level exceedances and provide a full interpretation and/or explanation as to why these levels were exceeded, the likely effects and detail any remedial or mitigation measures initiated as a result of these trigger exceedances."

Condition No. S.7

b) Add reference to Figure E14.
c) Add reference to Figures G1, G2 and G3.

Condition No. S.10

Add condition that the owners approval is required prior to undertaking inspections on private property.

Condition No. S.16

This condition may require expanding once the slope stability assessments have been completed.

7. MANAGEMENT PLANS

7.1 Comments on Groundwater Management Plan

7.1.1 General Approach

The GWMP (Groundwater Management Plan – Appendix H of AGE) outlines groundwater monitoring, alert and alarm levels and contingency actions. Groundwater level monitoring is proposed along the 13 2D modelling sections assessed in the AGE plus at infill locations. The general approach to groundwater monitoring adopted by NZTA is considered appropriate.

Comments on the GWMP are as follows:

7.1.2 Groundwater Drawdown Contingency Measures

- *Retaining Walls and Tunnel*

  Artificial groundwater recharge via trenches is proposed in Section 5.1.1 and 5.1.2 of the GWMP.

  Artificial recharge by bores into the ECBF should also be listed as a contingency measure. Bore recharge of the ECBF was successfully carried out during the BNZ basement excavation (Queen Street, Auckland CBD) and is considered a feasible option.

7.1.3 Monitoring Bores

Details relating to monitoring bores are considered to be incomplete and the following is required:

i. Schedule of existing and proposed bores showing both indicative depths of piezometers and geologic units.

ii. Site plans at an appropriate scale to show monitoring bores beyond the expected extent of dewatering effects as defined by the $<5mm$ predicted settlement contour from Figure E14 (Appendix A). Plans to also show cross-section locations.

iii. All new bores are required to have:

- Geological log.
- Air development (standpipe piezometers).
- Hydraulic conductivity testing (standpipe piezometers).

7.1.4 Monitoring of WECBF

Section 6.1.7 of GWMP indicates that shallow bores are to be screened through fill, TGA and WPG . Table 4.3 of the AGSE shows similar m_v (coefficient of volume compressibility) values for the TGA, WPG and the WECBF. Hence monitoring groundwater levels within the ECBF should also be carried out.

7.1.5 Monitoring Frequency

Groundwater level monitoring frequency is considered appropriate.

Post construction monitoring in the Sector 8 Tunnel area should commence from when the tunnels are permanently lined.

7.1.6 Alert and Alarm Levels

The alert levels are considered appropriate. The alarm levels for shallow and deep bores within 50*m* of the tunnel are also acceptable.

The alarm levels for shallow and deep bores >50*m* of the tunnel are presently undefined. The alarm levels should be set in the GMP prior to construction commencing.

Report prepared by:

P I KELSEY
Senior Hydrogeologist

A H NELSON
Senior Geotechnical Engineer R3119-1
EARTHTECH CONSULTING LTD 23 December 2010

This report has been prepared solely for the benefit of you as our client with respect to the particular brief given to us, and data or opinions contained in it may not be used in other contexts or for any other purpose without our prior review and agreement.

9. REFERENCES

Earthtech (1999) — Geotechnical and Hydrogeological Investigation Report. North Waikato Regional Landfill. Report prepared for EnviroWaste Services Limited. Ref 2319.

Earthtech (2010) — Quarterly Monitoring Report, Ihumatao Quarry Dewatering. Monitoring to 31 August 2010. Ref R2638-21, 8 October 2010

Fetter, C.W. (1994) — Applied Hydrogeology (3rd Edition), MacMillian College Publishing Company Inc.

Harding, B.C., *et.al* (2000) — Groundwater Response to the Dewatering of a Volcanic Vent. 11 Congress of IAEG, Auckland. CRC Press/Balkema Publications.

Namjoy, P. And Pattle, A. (2006) — Post-Audit of a Numerical Groundwater Flow Model developed for Britomart Transport Centre, Auckland, New Zealand. Proc. NZWWA 48th Conference, Christchurch 2006.

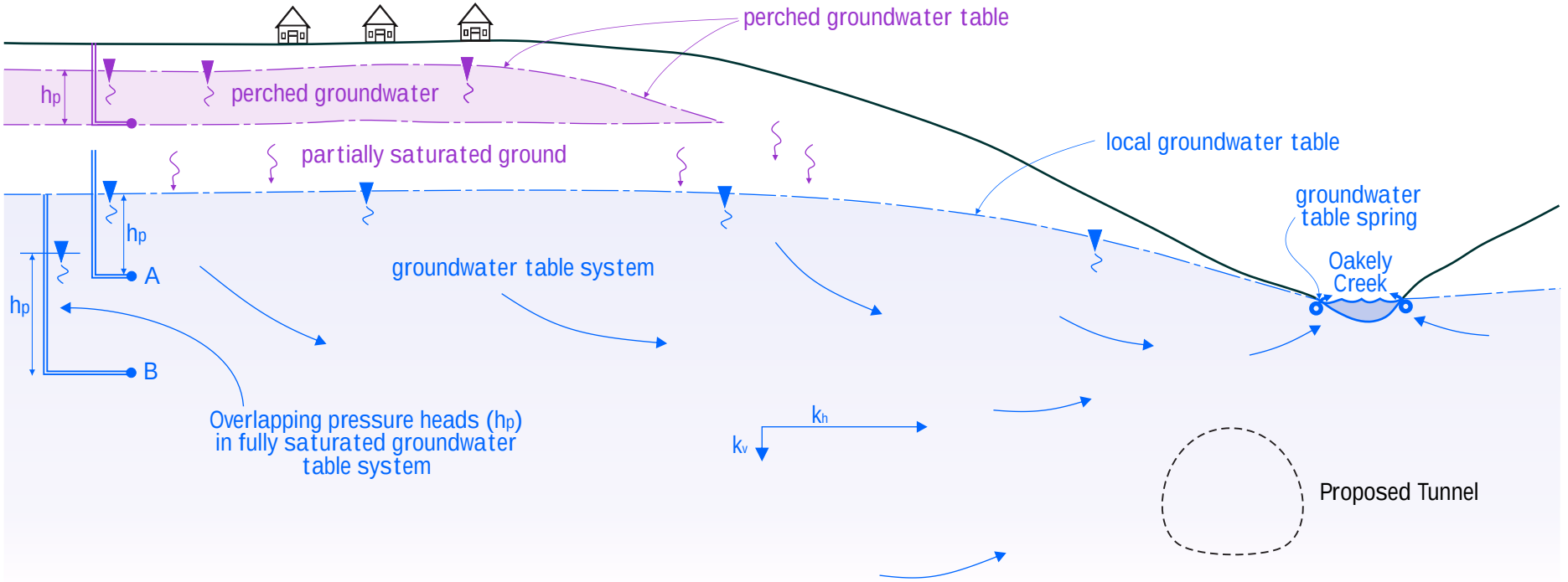
LEGEND

k = hydraulic conductivity
v = vertical
h = horizontal

Piezometer

h_p = water pressure head intake

WATERVIEW RIDGE



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WATERVIEW CONNECTION
Ministry for the Environment

Perched and Groundwater Table Systems

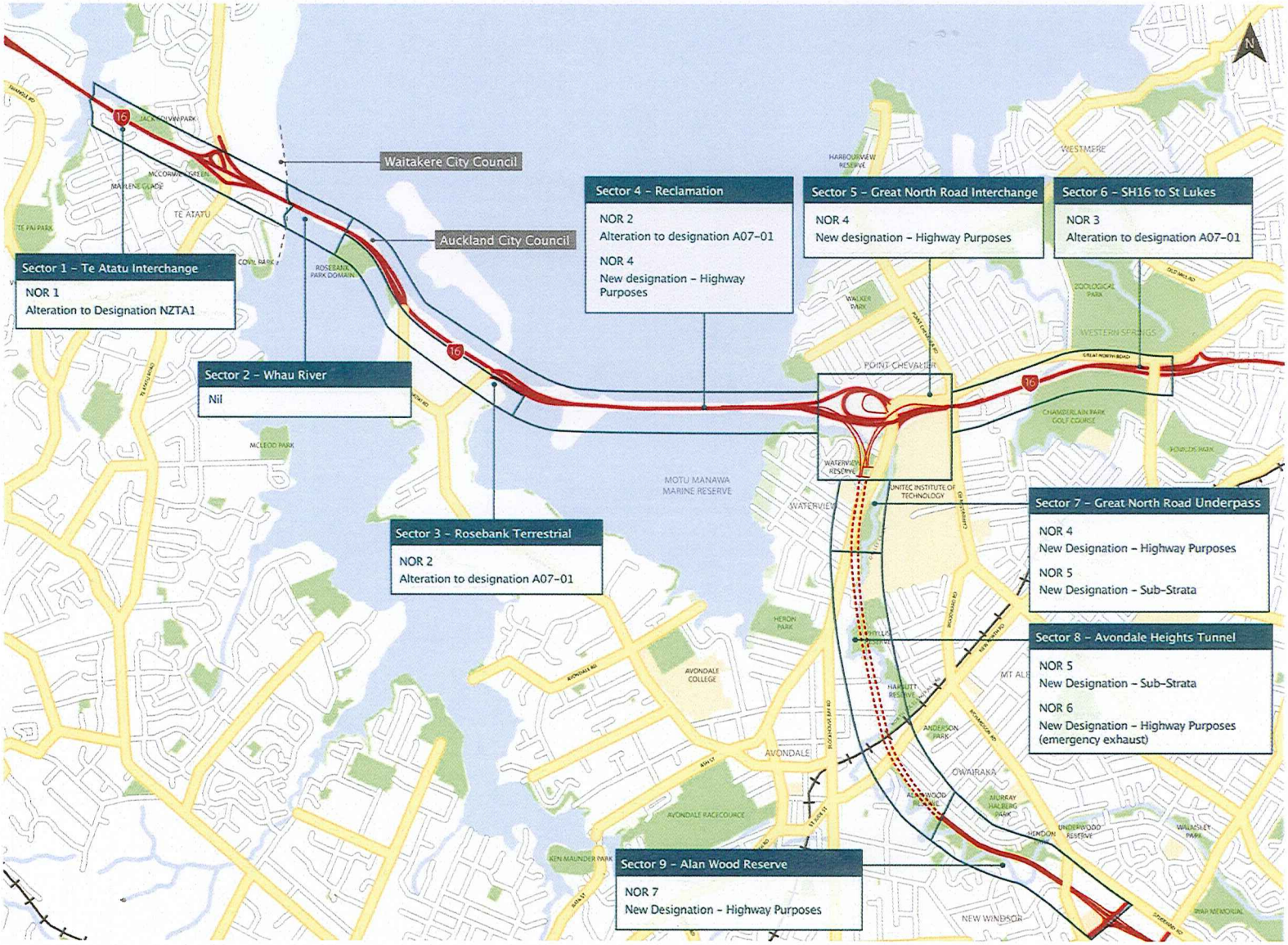
SHEET **FIG. 3.2**

DRAWN P.K	CHECKED P.K	SCALE (A4)	VERSION A
TRACED C.M/M.W	DATE 23/12/10	nts	REF 3119

APPENDIX A

Background Project Figures

ANNEXURE B: LOCATION OF PROJECT NORS



GIS@beca.com

SH 16

Point Chevalier South

CARRINGTON ROAD

ASQUITH AVENUE

4160

3940

Waterview

3880

3785

3400

3200

GREAT NORTH ROAD

BLOCKHOUSE BAY ROAD

MOUNT ALBERT ROAD

Mount Albert

NEW NORTH ROAD

2750

ASH STREET

Avondale North

2450

ST JUDE STREET

OWAIRAKA AVENUE

RICHARDSON ROAD

2160

NEW WINDSOR ROAD

STODDARD ROAD

1860

1780

1620

TIVERTON ROAD

1420

New Windsor

MAIORO STREET

Legend

- Settlement Analyses - Cross Section
- Proposed Alignment
- Cut & Cover Tunnel
- Southern Portal Building
- Driven Tunnel Extents

Total Estimated Settlement (mm)

- 5 mm - 10 mm
- 10 mm - 20 mm
- 20 mm - 50 mm
- 50 mm - 100 mm
- 100 mm - 200 mm
- > 200 mm

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Scale 1:5,000 at A1

0 100 200 400

Metres

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

N

Discipline: GIS

Project: SH20 Waterview Connection Combined Surface Tunnel

Beca

Drawing No: Figure E14

GIS@BECA.COM

Annexure B

Legend

Damage Category

- 1
- 2
- 3
- 4+5

Proposed Alignment

Settlement - Cross Sections

Path: P:\3814238\100\TGI\55_Workspaces\01_mxd\100503_DamageCategories\100503_DamageCategoriesA2.mxd

Scale 1:7,000 at A3

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Metres

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

N

Discipline: GIS

Drawing No: GIS-3814238-28

GIS@beca.com

Daventry Street

Herdman Street

Oakley Avenue

Alford Street

Alverston Street

Great North Road

4160

4160

3940

3880

3785

Waterview Primary School

BP Fuel Station

Unique foundation issue results in damage category '2' 1510 Great North Road, Unitec Residential Flats

Unitec Building 76

Legend

Damage Category

- 1
- 2
- 3
- 4+5

Proposed Alignment

Settlement - Cross Sections

Annexure B

Path: P:\3814238\100\TGI\55_Workspaces\01_mxd\100503_DamageCategories\100503_DamageCategoriesRev2.mxd

Scale 1:1,700 at A3

0 12.5 25 50

Metres

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 - 2

Client: **New Zealand Transport Agency**

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

N

Beca

Discipline: **GIS**

Drawing No: **GIS-3814238-18**

GIS@beca.com

Unique foundation issue results in damage category '2' 1510 Great North Road, Unitec Residential Flats

Unitec Building 76

1550 Great North Road

Tutukiki Street

Fir Street

Accessway

Waterview Downs

Fairlands Avenue

Great North Road

Laurel Street

3400

3200

Metro Football Clubhouse

Annexure B

Legend

Damage Category

- 1
- 2
- 3
- 4+5

Proposed Alignment

Settlement - Cross Sections

Path: P:\3811381\4238\100\TG\55_Workspaces\01_mxd\100503_DamageCategories\100503_DamageCategoriesRev2.mxd

Scale 1:1,700 at A3

0 12.5 25 50

Metres

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

N

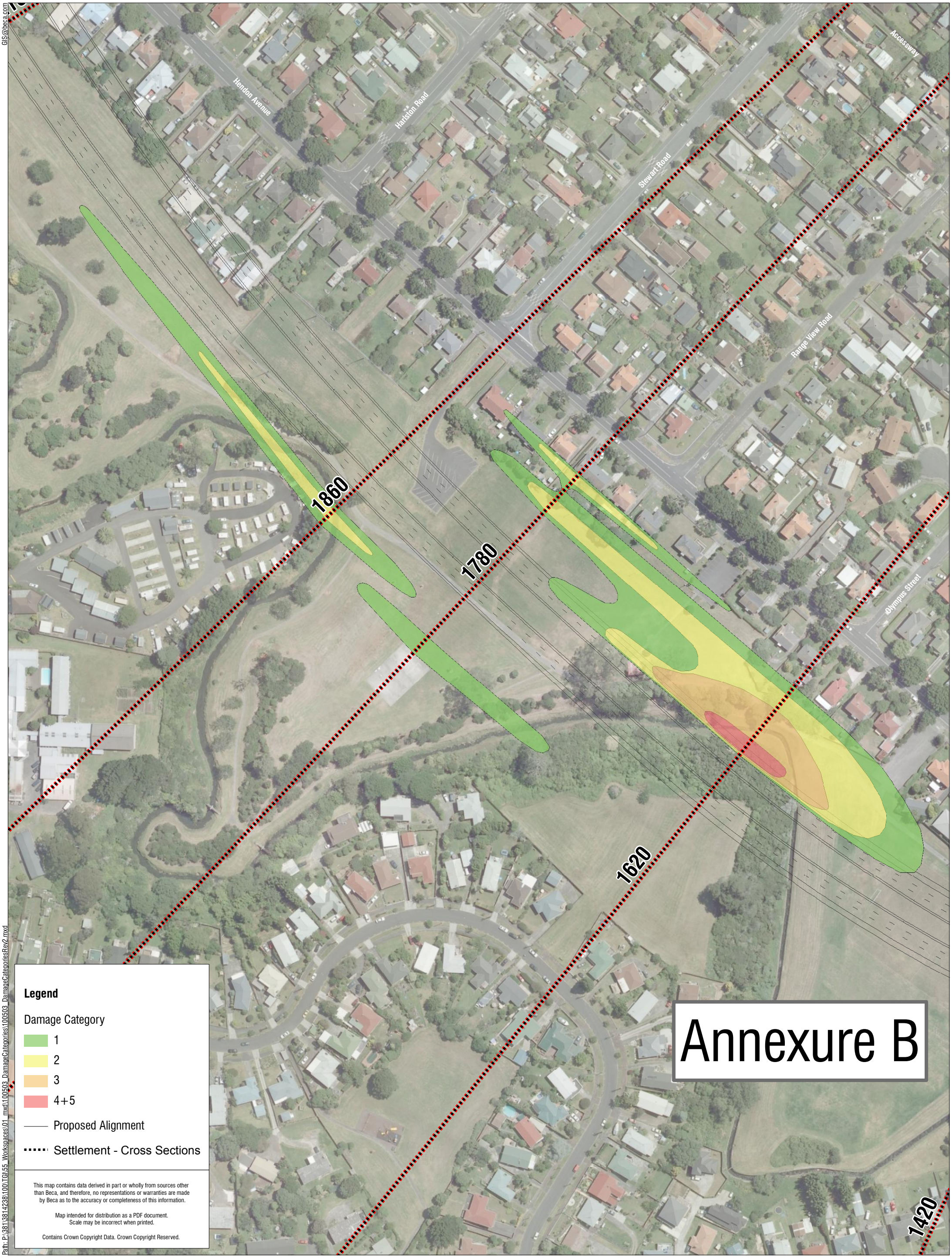
Discipline: GIS

Project: SH20 Waterview Connection Combined Surface Tunnel

Beca

Drawing No: GIS-3814238-18

GIS@beca.com



Legend

Damage Category

- 1
- 2
- 3
- 4+5
- Proposed Alignment
- Settlement - Cross Sections

Annexure B

Scale 1:1,700 at A3

0 12.5 25 50

Metres

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

N

Beca

Discipline: GIS

Drawing No: GIS-3814238-18

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APPENDIX B

Ch2750*m* 2D Groundwater Check Modelling
and Settlement Assessment

B1. CH2750*m* CONCEPTUAL MODEL DEVELOPMENT

Figure A1 provides the basis of the interpretation of perched and groundwater table systems. Perched groundwater is separated by the groundwater table system by partially saturated ground. Due to this "hydraulic disconnection", perched groundwater is not expected to be influenced by tunnelling effects. The local groundwater table represents the top of the "fully saturated" zone where all h_p (pressure head) ≥ 0 below this level. Between the top of the groundwater table and the base of the perched systems, h_p will be negative.

Figure A2 shows a h_p plot for BH508 located on Ch2750*m* on the central ridge associated with Waterview Heights. Figure A2 shows the top of the groundwater table at a shallow depth at RL46.5 (MB20) to RL50.1 (BH508c). Fully saturated conditions from near the top of the WPG/WECBF are indicated by the nested piezometer data. The hydraulic gradient is downwards and ranges i_v = 0.260 to 0.504 within ECBF. MB20 is a conventional piezometer. The high h_p = 20*m* at MB20 supports the BH508c vibrating wire piezometer where h_p = 23.1m.

Figure A3 shows the Ch2750*m* geology and a sketch flow net from monitored summer low groundwater levels. The NZTA Ch2750*m* geology is accepted apart from a lower rock-head under the centre of Waterview Ridge (at RL36m on the basis of local bore data). The conceptual groundwater model shows the following:

- Significant mounding of the groundwater table under Waterview Ridge.
- Significant recharge from Waterview Ridge.
- Secondary recharge east of Oakley Stream.
- Local discharge to Oakley Stream.
- Limited extent of perched groundwater (restricted to BH522S).

The above has formed the basis of the numerical modelling.

Groundwater tables are also plotted on Figure A3 from the NZTA AGE-G7 (2010 – provided by email 26 August 2010 in response to review queries) and NZTA AGE-G31 (2010) reports which demonstrate the significant differences between the conceptual models adopted by Earthtech and NZTA.

B2. Ch2750*m* 2D NUMERICAL GROUNDWATER MODELLING

B2.1 Model

The numerical modelling has been carried out using FEFLOW a commercially available finite element model supported by DHI-WASY in Germany.

The Ch2750*m* section was constructed as a 2D vertical projection.

B2.2 Calibration

Initially calibration was carried out by adjusting k_v (vertical hydraulic conductivity) within a range of rainfall recharge values so that a match between observed and calculated heads was achieved.

The calibration was run to achieve steady-state conditions.

The calibrated model settings and justification are summarised as follows:

i. k_h – Horizontal Hydraulic Conductivity

Unit	k_h	**Comment**
ECBF Rock	5.7 x 10^{-7}*m/s*	NZTA (2010a) setting
WECBF	2.0 x 10^{-7}*m/s*	NZTA (2010a) setting
W Parnell Grit	1.0 x 10^{-7}*m/s*	Geometric mean of in-situ *k* testing (NZTA AGE-G7 2010 Report)
TGA	1.0 x 10^{-7}*m/s*	NZTA (2010a) setting
Basalt	5.0 x 10^{-5}*m/s*	NZTA (2010a) setting

ii. k_h/k_v – Anisotropy

Unit	*A*	Comment
ECBF	40	Calibration range considered to be between A = 10 to 45 from Queen Street Station Auckland CBD, A = 10 (PDP, 2000) and North Waikato Landfill A = 45 (ET, 1999)
WECBF	20	Calibration range considered to be between A = 10 to 50 on basis of Auckland projects and PDP (2000)
W Parnell Grit	20	
TGA	20	Calibration range considered to be between A = 10 to 50 on basis of Auckland projects and PDP (2000)
Basalt	1	NZTA (2010a) setting.

iii. Recharge

- RHS model over basalt — R = 3% rainfall (limited to avoid groundwater "over-topping" TGA deposits adjacent to Oakley Stream)
- LHS model
  - Waterview Ridge — R = 8% rainfall
  - West of Waterview Ridge — R = 6% rainfall

iv. Boundary Conditions

- Model base at RL-100*m*, no flow boundary. Model base extended from RL-40*m* to RL-100*m* to incorporate conceptual model flow field (Fig A3).
- RHS – no flow boundary as located near groundwater divide.
- LHS – RL7*m* CHB from Figure 3a (NZTA AGE-G7 2010 Report).
- Oakley Stream – seepage boundary condition.

The model calibration is presented on Figure A4 with head data summarised in Table A1.

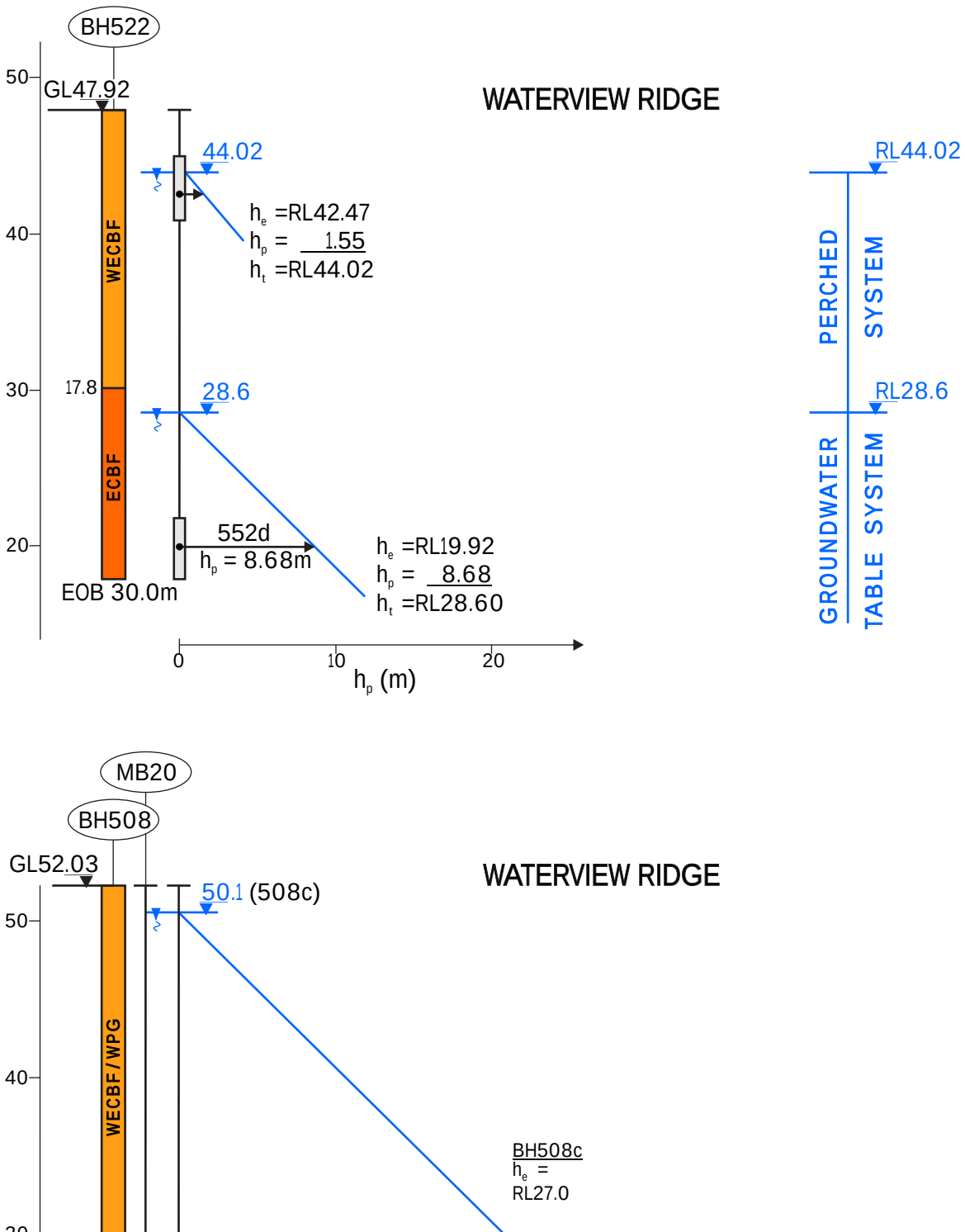
The Earthtech Ch2750*m* model shows improved calibration compared with the NZTA Ch2750*m* model (NZTA, 2010a) with a lower RMS.

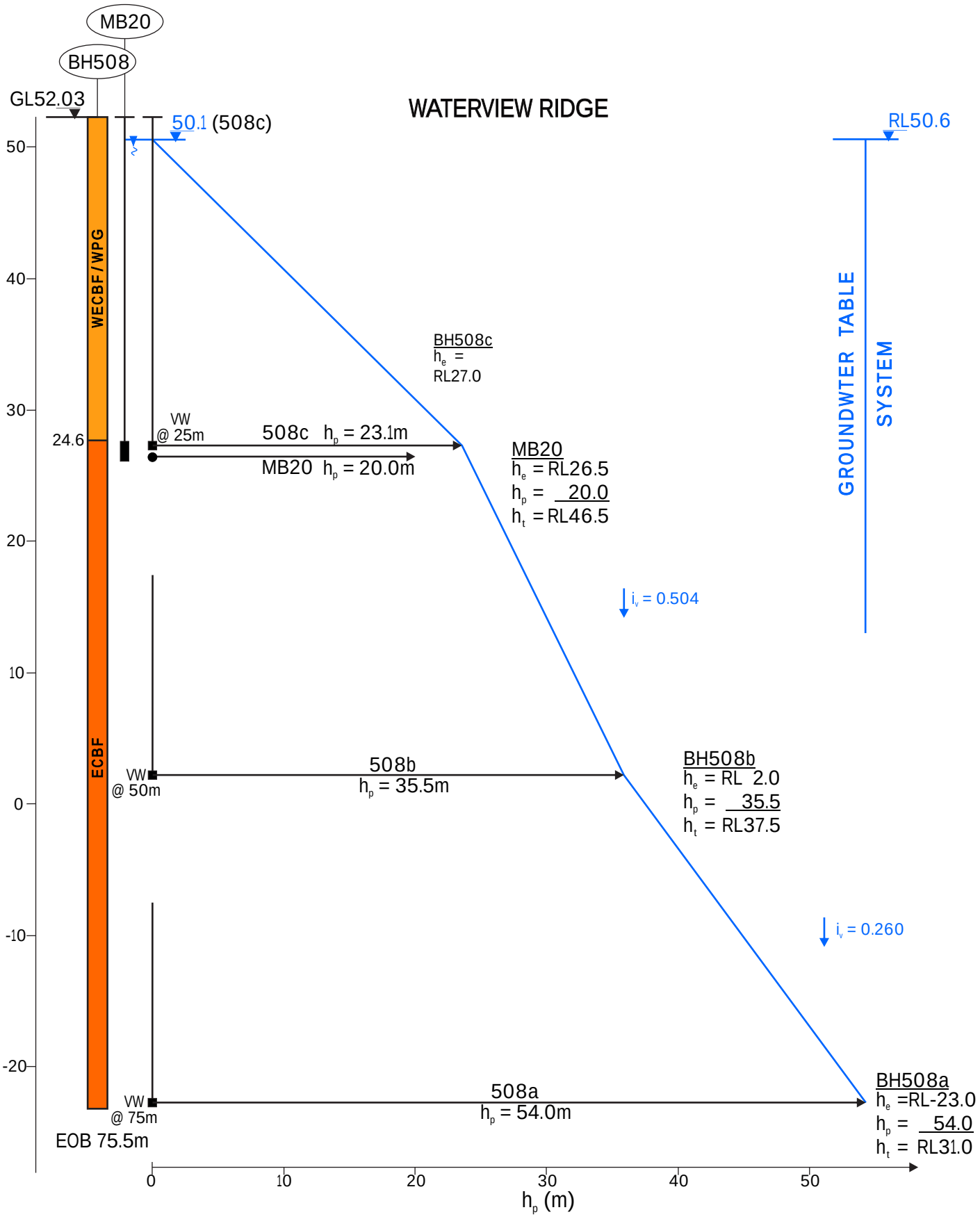
B3. GROUND SETTLEMENT

The above Earthtech Ch2750*m* check model incorporates a greater extent of potentially compressible WECBF and WPG compared with the NZTA Ch2750*m* models. Hence a greater extent of drawdown related settlement is expected for the Earthtech Ch2750*m* model compared with the predictions presented in NZTA (2010 – G7) and NZTA (2010 – G31).

Table B1 - Ch 2750m 2D Modelling Section Calibration Data

		Earthtech Check Model				*NZTA Model*			
Piezometer Location	***Observed Head*** h_t	***Calculated Head*** h_t	***Residuals*** r m	r^2 m^2		***Calculated Head*** h_t	***Residuals*** r m	r^2 m^2	
BH522d	28.6	33.0	4.4	19.4		37.3	8.7	75.7	
MB20	46.5	36.4	-10.1	102.0		35.9	-10.6	112.4	
BH508b	37.5	32.1	-5.4	29.2		35.3	-2.2	4.8	
BH508a	31.0	30.0	-1.0	1.0		35.1	4.1	16.8	
BH518s	33.0	34.7	1.7	2.9		34.0	1.0	1.0	
BH518d	31.9	33.2	1.3	1.7		33.8	1.9	3.6	
BH703a	25.0	32.2	7.2	51.8		33.8	8.8	77.4	
BH307s	32.5	34.9	2.4	5.8		34.2	1.7	2.9	
BH307d	30.9	33.3	2.4	5.8		34.0	3.1	9.6	
		RMS (Root Mean Square)		**4.9**	**m**	**RMS (Root Mean Square)**		**5.8**	**m**





LEGEND

h_e	Elevation Head
h_p	Pressure Head
h_t	Total Head
i_v	Vertical Hydraulic Gradient

NOTES:
- VW = vibrating wire piezometer
- Groundwater levels from 1 April 2010

Figure ET6c

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WATERVIEW CONNECTION
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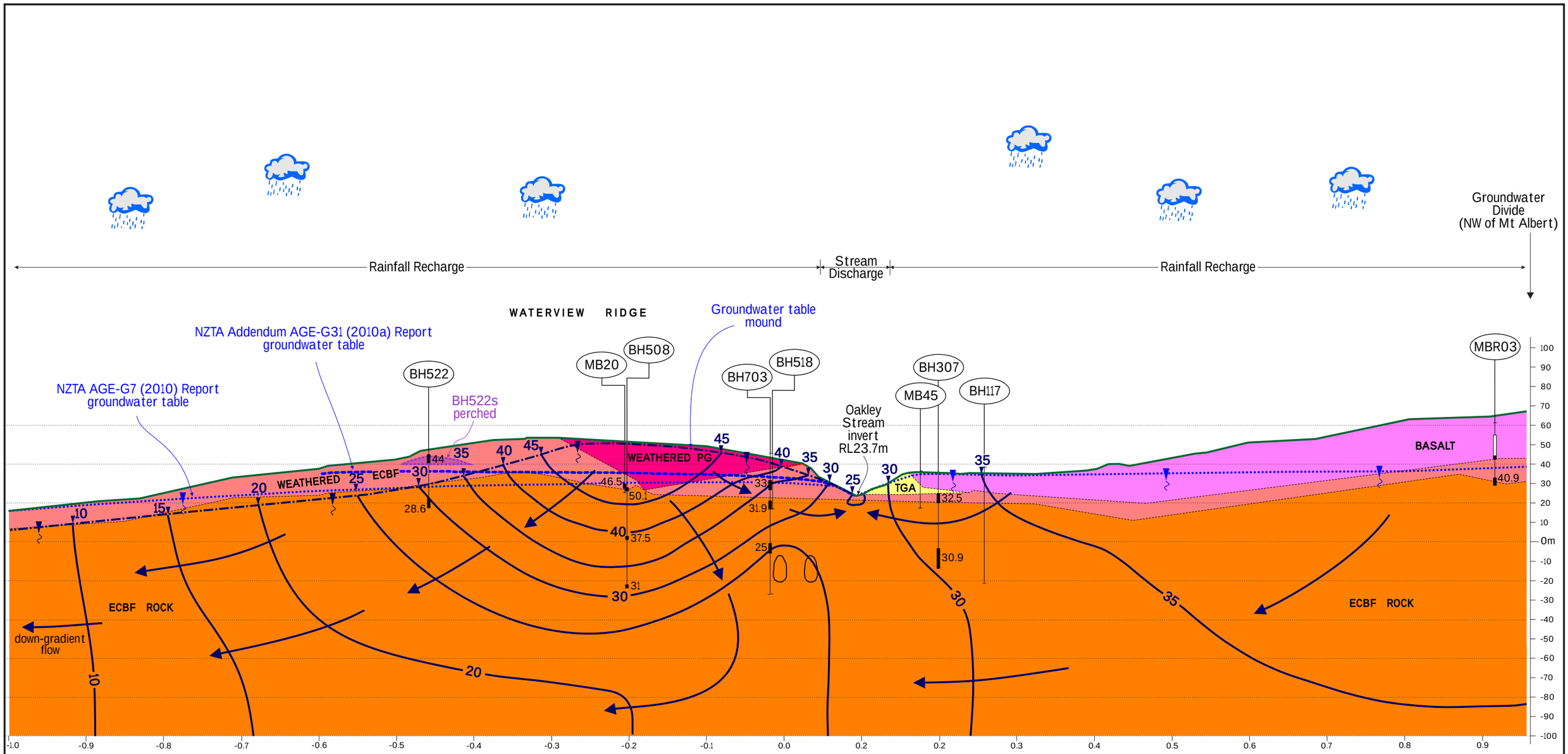
BH508 h_p Plot

SHEET **FIG. B1**

DRAWN P.K	CHECKED P.K	SCALE (A3)	VERSION A
TRACED C.M/M.W	DATE 22/12/10	1 : 400	REF 3119



LEGEND

- piezometer intake (30.9)
- h_e (summer low)
- sketch flownet (35)
- Groundwater flow direction

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WATERVIEW CONNECTION
Ministry for the Environment

Ch2750m Conceptual Groundwater Model

SHEET **FIG. B2**

DRAWN	P.K	CHECKED	P.K	SCALE (A3) 1:5000 (h) 1:2000 (v)	VERSION A
TRACED	C.M	DATE	22 Dec 2010		REF 3119

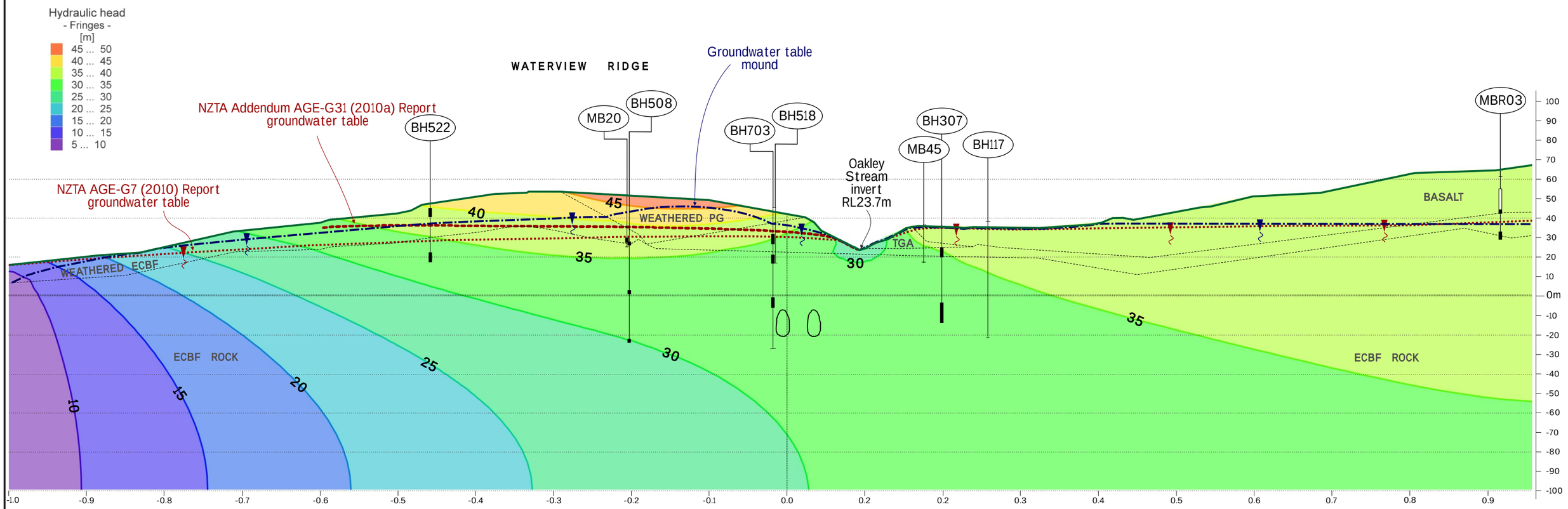

Figure B3a: Ch2750m Earthtech Calibrated FEFLOW Model

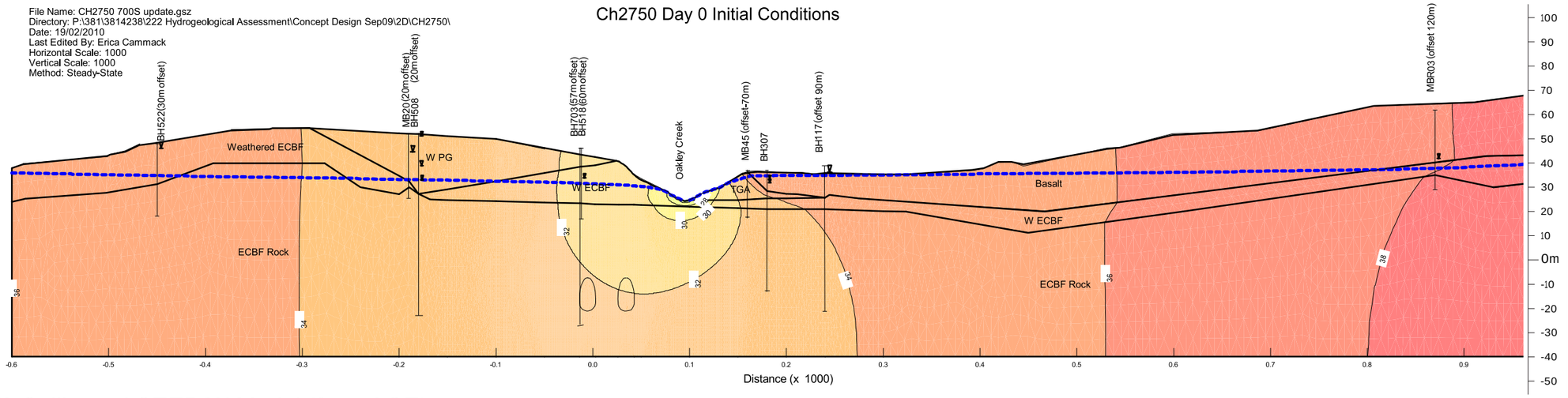

Figure B3b: Ch2750m NZTA Calibrated SEEP/W Model (from AGE)

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WATERVIEW CONNECTION
Ministry for the Environment

Ch2750m Calibrated Models

DRAWN	P.K	CHECKED	P.K	SCALE (A3) 1:5000(h) 1:2000(v)	SHEET FIG. B3
TRACED	C.M/M.W.	DATE	22 Dec 2010		VERSION A
					REF 3119

APPENDIX C

Recommended Changes to Conditions

Appendix C1 – Groundwater Conditions
Appendix C2 – Ground Settlement Conditions

APPENDIX C1

Groundwater Conditions

Earthtech edits in green.

Proposed Groundwater Conditions

Authorised Quantity: The Consent Holder shall ensure that: a. During excavation and construction the daily quantity diverted and taken shall not exceed: • Northern Portal and Approaches 800m³ • Tunnels 41,250m³ • Southern Portal and Approaches 11,760m³/d b. Following completion of excavation and construction the daily quantity diverted and taken shall not exceed: • Northern Portal and Approaches 280m³ • Tunnels 175m³ • Southern Portal and Approaches 225m³	
G.1	The NZTA shall finalise, and implement through the CEMP, the Groundwater Management Plan (GWMP), submitted with this application ~~and provide it to the [Auckland Council]~~ prior to commencement of ~~tunnelling~~construction dewatering. The GWMP shall include, but not be limited to: (a) The location of the groundwater monitoring bores; (b) The location of the continuous monitoring stations on Oakley Creek; (c) The methods and frequency for groundwater monitoring; (d) The groundwater trigger levels; (e) Procedures to follow in the event of trigger levels being exceeded; (f) Reporting requirements. ~~(f)~~ The NZTA shall submit the GWMP to the Auckland Council three months prior to the commencement of construction dewatering to gain written approval of the Manager prior to the exercise of this consent.;
G.2	The NZTA shall install and maintain the groundwater monitoring boreholes shown in Appendix A of the GWMP, for the period of monitoring specified in this Consent.
G.3	The NZTA shall monitor groundwater levels in the groundwater monitoring boreholes shown in Appendix A of the GWMP and keep records of the water level measurement and

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Proposed Groundwater Conditions

G.4	The NZTA shall monitor groundwater levels monthly in existing boreholes and in newly installed monitoring boreholes shown in Appendix A of the GWMP (required as part of this consent, as far as practicable) for a period of at least 12 months before the commencement of tunnelling. The variability in groundwater levels over this period, together with the monitoring trends obtained during the investigation and detailed design phases, will be used to establish seasonal groundwater level variability and establish trigger levels.
G.5	Prior to the commencement of tunnelling, and then at 3 monthly intervals while tunnelling, the NZTA shall review the results of monitoring as compared with expected effects on groundwater levels due to tunnelling. This review will consider the final tunnel alignment construction methodology and progress at the time of the review. The output of the first review shall be used to define the expected range of groundwater levels at each borehole during tunnelling activities and check the potential for damage to structures due to ground settlement. A factor for natural seasonal variability shall be allowed for in this review based on the monitoring completed under Condition G.4.
G.6	From commencement of tunnelling, the NZTA shall monitor groundwater levels in each borehole at a minimum of monthly intervals and records shall be kept of each monitoring date and the corresponding water level in each borehole. In addition, all boreholes located within 100 metres of the tunnel excavation face shall be monitored for groundwater level at least twice weekly. These records shall be compiled and submitted to the Auckland Council at three monthly intervals.
G.7	From commencement of tunnelling, the NZTA shall monitor groundwater level in boreholes established in the Phyllis Street Reserve. Should water levels rise more than 0.6 m above the highest recorded pre-construction water level in the period where tunnelling is taking place within 100 m of the Reserve, then an inspection of the surface of the landfill will be made and the surface re-levelled in areas where cracking of the cap or ponding of water on the surface is indicated (other than exists prior to commencement of the works). The NZTA shall also monitor groundwater quality in bores between the Phyllis Street Landfill and the tunnel. Monitoring of leachate indicators (pH, conductivity, chloride, ammonium and boron) to be carried out at three monthly intervals when tunnel construction is within 100m of the landfill and continue until permanent tunnel lining has been constructed.
G.8	All monitoring data obtained pursuant to Condition G.6 shall be compared to the predicted groundwater levels for each borehole. Where groundwater levels are exceeded the appropriate actions as set out in the GWMP shall be undertaken and the Auckland Council shall be notified, forthwith, advising of the exceedance, the risk of settlement that might cause damage to structures or adverse effects in Oakley Creek, and details of the actions undertaken.

Proposed Groundwater Conditions

G.9	The NZTA shall continue to monitor groundwater levels in each borehole at monthly intervals for a period of up to 12 months following completion of tunnelling, then 3 monthly thereafter for a further 24 months, or for a lesser period if groundwater levels in any particular borehole show either: (a) Recovery of the groundwater level to within 2 metres of the pre-tunnelling groundwater level as recorded in accordance with Condition G.5; or, (b) A trend of increasing groundwater level in at least 3 consecutive monthly measurements; or, (c) An equilibrium in the groundwater level, allowing for the seasonal variation, has been reached, In which case monitoring at that borehole may cease, subject to the written approval of the Auckland Council.
G.10	The NZTA shall design and construct the tunnels and approaches as described in the Geotechnical Interpretive Report (G.24 dated July 2010).
~~G.10~~G.1	The NZTA shall establish continuous flow monitoring stations at the following approximate locations within Oakley Creek: (a) Chainage 1800 – 1900 (Waterview Connection Operational Plan, Drawing No: 20.1.11-3-D-C-910-117); (b) Chainage 2200 (Waterview Connection Operational Plan, Drawing No: 20.1.11-3-D-C-910-116); (c) Chainage 3500 (Waterview Connection Operational Plan, Drawing No: 20.1.11-3-D-C-910-114); (d) Between Chainage 3900 to 4200 ((Waterview Connection Operational Plan, Drawing No: 20.1.11-3-D-C-910-113); The NZTA shall establish a continuous flow monitoring station at the upstream major tributary at Chainage 1000. The NZTA shall continue to monitor the flow monitoring station installed at CH2900 (Waterview Connection Operational Plan, Drawing No: 20.1.11-3-D-C-910-116). The exact location of the gauges shall be determined based on stream bed conditions such that they record the full range of flows as far as practical, with the locations detailed in the GWMP.

Proposed Groundwater Conditions

~~G.11~~G.1	The continuous monitoring required by Condition G.9, shall record in-stream flows, at 15 minute intervals, for a period of: (a) At least 12 months prior to tunnelling commencing; (b) During tunnelling; and (c) Up to 12 months following completion of tunnelling, or a shorter period if no effects on base flows are recorded.
~~G.12~~G.1	The continuous monitoring results shall be reviewed on a monthly basis to determine if there is any effect of the tunnelling on base flows in Oakley Creek. The results shall be included in the 3 monthly groundwater reports, and provided to the Auckland Council.
~~G.13~~G.1	The NZTA shall, within 10 working days of completion of tunnelling, advise the Manager Auckland Council, in writing, of the date of completion.

APPENDIX C2

Ground Settlement Conditions

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Proposed Ground Settlement Conditions

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].~~ 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. In the event that settlement predictions are greater (than E14) or building damage categories increase in ranking or number of buildings, mitigation measures shall be introduced as part of the detailed design and construction process to avoid any adverse effects greater than predicted by the Application lodged in August 2010.
	Settlement Monitoring
S.2	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: (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 and to infill between them. Either side of each cross-section shall include at least two markers within 20m of each other and no more than 150m out to determine the differential movements. (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 and as may be updated to reflect detailed analysis and interpretation of monitoring results as the project proceeds. 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. Each marker shall have an alert and an alarm level set in relation to Figure E14 where alert = 75% of the theoretical value and alarm = 100% of the theoretical value.

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Proposed Ground Settlement Conditions

S.3	The NZTA shall survey the settlement monitoring markers at the following frequency: (a) Pre-construction i) All Framework Markers – Vertical and selected h~~H~~orizontal ~~and vertical~~ at 3 monthly intervals, starting at least 12 months prior to construction commencing; and ii) All Intermediate Markers – Vertical and selected h~~H~~orizontal ~~and vertical~~ once. (b) During Construction i) All Framework Markers – Vertical on a monthly basis; and ii) Selected Framework Markers only – Horizontal on a monthly basis. (c) During Active Construction i) All Framework and Intermediate Markers – Vertical on a weekly basis; and ii) Selected Framework Markers only – Horizontal on a monthly basis. "Active construction" shall be defined as: (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.
S.4	~~Immediately following each monitoring round, the NZTA shall use the settlement monitoring results (together with the results of groundwater monitoring where they may provide an earlier indication of future settlements) to reassess the ground settlements and building damage categories and compare them to those estimated in Technical Report G.13 *Assessment of Ground Settlement Effects*, submitted with this application the SEMP. If the reassessment indicates that a building has increased its damage category from that in Technical Report G.13 *Assessment of Ground Settlement Effects*, the SEMP, 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.~~ If alert and alarm levels are exceeded, the trigger marker shall be resurveyed immediately and reported to the Manager (Auckland Council). The pairs of "differential settlement markers" shall be checked after each survey and an alert triggered if the differential exceeds 1 in 1000 and alarm triggered if the differential exceeds 1 in 500.

Proposed Ground Settlement Conditions

S.5	The NZTA may reduce the frequency of settlement monitoring to 6 monthly: (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. Settlement monitoring shall be undertaken for a period of 2 years following completion of the tunnels.
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). The settlement reports shall highlight any alert or alarm level exceedances and provide a full interpretation and/or explanation as to why these levels were exceeded, the likely effects and detail any remedial or mitigation measures initiated as a result of these trigger exceedances.
	Building Condition Surveys

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Proposed Ground Settlement Conditions

S.7	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 *Assessment of Ground Settlement Effects* provided in support of this application: (a) Buildings on properties within the substrata designation; (b) Buildings where total estimated settlement is greater than 50mm (defined in Figure E14); (c) Buildings in areas estimated to have a risk of damage more than negligible (defined in Figures G1, G2 and G3 as Categories 1 to 5); (d) Unitec Building 76; (e) 1510 Great South Road, Unitec Residential Flats (two buildings); (f) Pak'n'Save 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~~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 (e.g. a Chartered Professional Engineer) to undertake the building assessments required pursuant to Condition S.7 and identify this person in the SEMP.
S.10	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: (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; and (f) Waterview Primary School (pool and hall). Note: Type 1 and 2 Dwellings are those as defined in Technical Report G.13 *Assessment of Ground Settlement Effects.* Inspections shall only be undertaken with the approval of the

Proposed Ground Settlement Conditions

S.11	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: (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); and (d) Waterview Primary School (pool)
S.12	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 NZTA shall agree appropriate remedial works (if any) and arrangements for implementing them with the owner. 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.
S.13	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.
	Retaining Wall Monitoring
S.14	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.
	Services Monitoring
S.15	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: (a) Waterview Orakei No. 9 trunk sewer. 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

Proposed Ground Settlement Conditions

	Slope Stability Assessments
S.16	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: (a) 14H and 14J Cradock Street (b) 34 Cradock Street (c) 40 Cradock Street (d) 56 Powell Street; and (e) 1590A Great North Road. 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.

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Proposed Groundwater Conditions

Authorised Quantity: The Consent Holder shall ensure that:

a. During excavation and construction the daily quantity diverted and taken shall not exceed:

- Northern Portal and Approaches 800m³
- Tunnels 41,250m³
- Southern Portal and Approaches 11,760m³/d

b. Following completion of excavation and construction the daily quantity diverted and taken shall not exceed:

- Northern Portal and Approaches 280m³
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G.1	The NZTA shall finalise, and implement through the CEMP, the Groundwater Management Plan (GWMP), submitted with this application ~~and provide it to the [Auckland Council]~~ prior to commencement of ~~tunnelling~~construction dewatering. The GWMP shall include, but not be limited to: (a) The location of the groundwater monitoring bores; (b) The location of the continuous monitoring stations on Oakley Creek; (c) The methods and frequency for groundwater monitoring; (d) The groundwater trigger levels; (e) Procedures to follow in the event of trigger levels being exceeded; (f) Reporting requirements. ~~(f)~~ The NZTA shall submit the GWMP to the Auckland Council three months prior to the commencement of construction dewatering to gain written approval of the Manager prior to the exercise of this consent.~~;~~
G.2	The NZTA shall install and maintain the groundwater monitoring boreholes shown in Appendix A of the GWMP, for the period of monitoring specified in this Consent.
G.3	The NZTA shall monitor groundwater levels in the groundwater monitoring boreholes shown in Appendix A of the GWMP and keep records of the water level measurement and corresponding date in accordance with the GWMP. These records shall be compiled and submitted to the Auckland Council at three monthly intervals.

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Proposed Groundwater Conditions

G.4	The NZTA shall monitor groundwater levels monthly in existing boreholes and in newly installed monitoring boreholes shown in Appendix A of the GWMP (required as part of this consent, as far as practicable) for a period of at least 12 months before the commencement of tunnelling. The variability in groundwater levels over this period, together with the monitoring trends obtained during the investigation and detailed design phases, will be used to establish seasonal groundwater level variability and establish trigger levels.
G.5	Prior to the commencement of tunnelling, and then at 3 monthly intervals while tunnelling, the NZTA shall review the results of monitoring as compared with expected effects on groundwater levels due to tunnelling. This review will consider the final tunnel alignment construction methodology and progress at the time of the review. The output of the first review shall be used to define the expected range of groundwater levels at each borehole during tunnelling activities and check the potential for damage to structures due to ground settlement. A factor for natural seasonal variability shall be allowed for in this review based on the monitoring completed under Condition G.4.
G.6	From commencement of tunnelling, the NZTA shall monitor groundwater levels in each borehole at a minimum of monthly intervals and records shall be kept of each monitoring date and the corresponding water level in each borehole. In addition, all boreholes located within 100 metres of the tunnel excavation face shall be monitored for groundwater level at least twice weekly. These records shall be compiled and submitted to the Auckland Council at three monthly intervals.
G.7	From commencement of tunnelling, the NZTA shall monitor groundwater level in boreholes established in the Phyllis Street Reserve. Should water levels rise more than 0.6 m above the highest recorded pre-construction water level in the period where tunnelling is taking place within 100 m of the Reserve, then an inspection of the surface of the landfill will be made and the surface re-levelled in areas where cracking of the cap or ponding of water on the surface is indicated (other than exists prior to commencement of the works). The NZTA shall also monitor groundwater quality in bores between the Phyllis Street Landfill and the tunnel. Monitoring of leachate indicators (pH, conductivity, chloride, ammonium and boron) to be carried out at three monthly intervals when tunnel construction is within 100m of the landfill and continue until permanent tunnel lining has been constructed.
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Proposed Groundwater Conditions

G.9	The NZTA shall continue to monitor groundwater levels in each borehole at monthly intervals for a period of up to 12 months following completion of tunnelling, then 3 monthly thereafter for a further 24 months, or for a lesser period if groundwater levels in any particular borehole show either: (a) Recovery of the groundwater level to within 2 metres of the pre-tunnelling groundwater level as recorded in accordance with Condition G.5; or, (b) A trend of increasing groundwater level in at least 3 consecutive monthly measurements; or, (c) An equilibrium in the groundwater level, allowing for the seasonal variation, has been reached, In which case monitoring at that borehole may cease, subject to the written approval of the Auckland Council.
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Proposed Groundwater Conditions

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	Settlement Monitoring
S.2	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: (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 and to infill between them. Either side of each cross-section shall include at least two markers within 20m of each other and no more than 150m out to determine the differential movements. (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 and as may be updated to reflect detailed analysis and interpretation of monitoring results as the project proceeds. 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. Each marker shall have an alert and an alarm level set in relation to Figure E14 where alert = 75% of the theoretical value and alarm = 100% of the theoretical value.

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Proposed Ground Settlement Conditions

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Proposed Ground Settlement Conditions

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Proposed Ground Settlement Conditions

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S.12	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 NZTA shall agree appropriate remedial works (if any) and arrangements for implementing them with the owner. 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.
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S.14	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.
	Services Monitoring
S.15	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: (a) Waterview Orakei No. 9 trunk sewer. 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.

Proposed Ground Settlement Conditions

	Slope Stability Assessments
S.16	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: (a) 14H and 14J Cradock Street (b) 34 Cradock Street (c) 40 Cradock Street (d) 56 Powell Street; and (e) 1590A Great North Road. 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.