Roads of national significance

Ara Tūhono – Pūhoi to Wellsford

This document records technical and factual information used to support the NZTA's Assessment of Environmental Effects for the Pūhoi to Warkworth Project. It has been supplied to the Environmental Protection Authority by the NZTA in response to a section 149(2) Resource Management Act 1991 request. This document did not form part of the NZTA's application for the Project, which was lodged on 30 August 2013.

Pūhoi to Warkworth

Geotechnical Engineering Appraisal Report

August 2013

Pūhoi to Warkworth

Document title: Geotechnical Engineering Appraisal Report

Version: Final

Date: 20 August 2013

Prepared by: Darryn Wise, Grant Murray, Ollie Hawes, Ross Kendrick

Ross Kendrick.

Approved by: Tony Innes

File name: 500-053 Geotechnical Engineering Appraisal Report_Final_20 August 2013

Further North Alliance Office
Level 2, Carlaw Park
12-16 Nicholls Lane
Parnell, Auckland
New Zealand

Tel: 0800 P2W NZTA (0800 729 6982)

Email: puhoi-wellsford@nzta.govt.nz

Tel: www.nzta.govt.nz/projects/Puhoi-wellsford

Glossary of abbreviations

Abbreviation	Definition
AEE	Assessment of Environmental Effects
ALPURT	Albany to Pūhoi Realignment
API	Aerial Photograph Interpretation
BH	Borehole
Ch	Chainage
CPT	Cone Penetration Test
CW	Completely Weathered
DEM	Digital Elevation Model
DSM	Deep-soil mixing
GNS	GNS Science (Institute of Geological and Nuclear Sciences Limited)
HW	Highly Weathered
kN	Kilonewtons
kPa	Kilopascals
mBGL	Metres below ground level
MPa	Mega Pascals
MSE	Mechanically Stabilised Earth
MW	Moderately Weathered
NCEER	National Center for Earthquake Engineering Research
NGA	Northern Gateway Alliance
NGTR	Northern Gateway Toll Road
NZGS	New Zealand Geotechnical Society
NZS	New Zealand Standard
NZTA	NZ Transport Agency

Abbreviation	Definition
PGGAR	Preliminary Geological and Geotechnical Appraisal Report
RL	Reduced Level
RoNS	Roads of National Significance
SKM	Sinclair Knight Merz
SPT	Standard Penetration Test
SW	Slightly Weathered
UCS	Unconfined Compressive Strength
UW	Unweathered

Glossary of defined terms

Term	Definition
Active (landslide)	Currently moving or a currently unstable site which displays a cyclical pattern of movement with a periodicity of up to 5 years.
Allochthon	A large block of rock which has been moved from its original site of formation, usually by low angle thrust faulting (certain complexes within the Northland Allochthon have colloquially been known as “Onerahi Chaos”).
Alluvium	Material which has been eroded then transported by water and deposited in a non-marine setting. Materials are generally loose, unconsolidated soils.
Anchor	Something used to restrain movement i.e. a tie rod holding back a retaining wall.
Anticline fold	An upward, curved fold in the layers of rock where the oldest rocks occupy the core.
Auckland Council	The unitary authority that replaced eight councils in the Auckland Region as of 1 November 2010.
Bedding	A soil or rock surface parallel to the surface of deposition. Bedding in sedimentary rocks is usually observed as a series of parallel layers.
Borehole	A hole drilled into the ground to obtain information of the subsurface conditions, including material, stratigraphy and groundwater.
Bored pile retaining wall	A retaining wall constructed using piles formed by pouring concrete into a predrilled hole in the ground.
Buttress Fill	A designed, stabilised, compacted earth fill used to provide lateral support to an unstable earth or rock mass.
Cone Penetration Test	A site investigation method used to determine the geotechnical properties of soils. A hydraulic ram is used to push an instrumented cone through the subsoil at a controlled rate.
Corestone	A large cobble or boulder of relatively unweathered rock found within a deep weathering profile.
Counterfort Drains	Drains constructed with the purpose of draining high groundwater levels in slopes for ground stabilisation. The drains are constructed as a series of trenches backfilled with gravel.
Creep	Slow movement of surface/shallow soil downhill.

Term	Definition
Culvert	A pipe with an inlet from a watercourse and outlet to a watercourse, designed to convey water under a specific structure (such as a road).
Deep Soil Mixing	A soil improvement technology used to treat soils in situ to improve strength and stiffness, thereby improving bearing capacity and reducing compressibility. The process involves mixing a grout or binder with the soil in reciprocating augers to create cemented columns of improved soil.
Debris Flow	Fast flowing mixture of water with a medium or high proportion of solids, which moves down watercourses.
Dormant (landslide)	A landslide or site that remains stable under most conditions, but may be reactivated in part or as a whole by extreme conditions.
Earthworks	The disturbance of land surfaces by blading, contouring, ripping, moving, removing, placing or replacing soil or earth, or by excavation, or by cutting or filling operations.
Effective Stress	The average inter-granular (contact) stress between soil particles.
Engineered Fill	A fill which is selected, placed and compacted to a specification in order to meet the required engineering behaviour.
Erosion	The process whereby particles are detached from rock or soil and transported away.
Erosion Control	Methods to prevent or minimise the erosion of soil, in order to minimise the adverse effects that land disturbing activities may have on a receiving environment.
Excavation	Digging, breaking and removal of soil/rock.
Excavatability	The measure of how a rock material can be excavated by conventional machinery such as bulldozers, excavators etc.
Factor of Safety	In slope stability, the ratio of the resisting forces along a slip surface to the applied force.
Fault	A break in rock/soil representing blocks of material which have been displaced vertically and/or horizontally. Faults are rarely single units, but normally occur as parallel or sub-parallel sets of fractures along which displacement has taken place.
Frittering	An erosion effect, often due to the wetting and drying of clayey material. Visually observed in the Waitemata Group rocks as small sand or gravel size fragments of mudstone or siltstone material breaking off the outcrop surface.
Rockfall fence	A protective mesh fence used to catch falling rocks.

Term	Definition
Geogrid	A geosyntheic material (usually a polymeric product) used to reinforce soil in retaining walls, sub-bases or sub-soils below roads or structures.
Geological Structure	Any geological feature that can be defined geometrically for example, bedding, joints, fractures, faults.
Geomorphology	The study of the form of the ground surface, its relation to geology below it and the processes which formed it.
Ground Improvement (Ground Treatment)	Various methods used to strengthen or dewater the ground. For example see 'Stone Columns'
Groundwater	Natural water contained within soil and rock formations below the surface of the ground.
Earthflow	A movement of fine grained material downslope in which shear surfaces are usually not preserved. The displacing mass usually resembles that of a viscous liquid overlying a lower boundary of differential movement or distributed shear.
Horizontal drains	Horizontally drilled drains into a rock/soil used to lower water pressures in the ground.
Inactive (landslide)	A landslide or site of instability which is stable under prevailing conditions.
Indicative Alignment	A route and designation footprint selected after short-list and long-list development to enable consultation with the community. This development involved specialist work assessing environmental, social and engineering inputs.
Interbedded	When beds or layers of rock of one type regularly alternate with a different type.
Joint	A fracture of which any shear displacement is too small to observe with the naked eye. A series of parallel joints is called a joint set.
Lateral Spreading	The lateral movement of a gently to steeply sloping, saturated soil slope caused by earthquake induced liquefaction.
Limit Equilibrium	An analytical analysis technique used to assess the stability of natural or man-made slopes. It investigates the equilibrium of a soil mass tending to slide due to the influence of gravity.
Lineament	A major, linear, topographic feature evident in the landscape. This often reflects an underlying geological structure, such as fault zones or geological boundaries.

Term	Definition
Liquefaction	When the pore pressures increase in a saturated soil to the extent that the inter-granular (contact) stress between soil particles is reduced. Usually in response to an earthquake.
Mechanically Stabilised Earth (MSE) Walls	Internally reinforced soil structures with face angles ranging from 70 degrees to 90 degrees from the horizontal. Slope angles less than 70 degrees are termed reinforced soil slopes.
Overland Flow Path	The flow path of stormwater over the ground.
Packer Test	A method of measuring the permeability of strata in a borehole.
Permeability	Parameter used to define the ability of a soil or rock to permit groundwater flow or seepage.
Pier	Vertical support structure for a bridge.
Pile	A timber, steel, reinforced or precast concrete post driven, jacked or cast into the ground.
Standpipe Piezometer	A device used to measure the pressure of groundwater at a specific point. Generally constructed using a solid polyvinyl chloride case to a depth of interest, with a slotted or screened casing at the zone of which the water pressure is to be measured.
Perched water table	The surface of a perched aquifer – a locally developed water saturated body above the regional water table (i.e. in the unsaturated zone). This occurs when there is an impermeable layer of rock or sediment (aquiclude), or relatively impermeable layer (aquitard) above the main water table/aquifer but below the ground surface.
Plasticity (soil)	A characteristic index property of a soil. A high plasticity soil will be sensitive (lose strength) when disturbed and will experience volume change due to changes in moisture content.
Portal	The entrance way to a tunnel starting where the road is completely uncovered to where it is completely covered.
Project	Pūhoi to Warkworth section of the Ara Tūhono Pūhoi to Wellsford Road of National Significance Project.
Project Area	From the Johnstone's Hill tunnel portals in the south to Kaipara Flats Road in the north.

Term	Definition
Reclamation	Defined in the Auckland Regional Plan: Coastal as any permanent filling of an area previously inundated by coastal water either at or above mean high water spring mark, whether or not it is contiguous with the land, so that the filled surface is raised above the natural level of mean high water springs, and thus creates dry land, removed from the ebb and flow of the tide.
Reinforced Soil Slopes	Internally reinforced soil structures with face angles less than 70 degrees. Slope faces steeper than 70 degrees are termed mechanically stabilised earth (MSE) walls.
Residual Soil	Rock which, due to a natural weathering process, is completely changed to a soil with the original fabric destroyed.
Rockfall	A rapid movement of rock due to falling under gravity.
Rotational Landslide	A landslide which has a curved failure surface and a backward rotation of the failed mass.
Sediment Control	Capturing sediment that has been eroded and entrained in overland flow before it enters the receiving environment.
Seismic	Term related to earthquakes or other shaking of the earth's crust.
Sensitivity (soil)	The measure of the loss of strength that occurs when a soil is disturbed or remoulded. High sensitivity means high strength loss.
Settlement	The gradual sinking of the ground surface as a result of the compression or consolidation of underlying material.
Shear Keys	In-ground earth structures that improve the shearing resistance of foundation soils and usually involve deep excavations and the importation of engineered fill material.
Shear Pile	A pile that is designed to resist shear forces over a pre-existing shear zone.
Shear Surface	A surface upon which movement has occurred parallel to the surface orientation.
Shear Zone	A zone of deformation between two undeformed blocks of soil or rock, caused by shearing. May be caused by faulting or landsliding.
Soil Nailing	A ground stabilisation technique that involves inserting a reinforcing bar (rebar or steel rod) into a hole pre-drilled through the potentially unstable ground and grouting the hole, effectively 'nailing' the soil together to form a more competent block of soil.

Term	Definition
Stratigraphy	The layering of sedimentary or metamorphic rocks, with focus on relative age and continuity to other locations.
Stone Columns	A ground improvement technique that introduces dense granular soils in vertical columns into weak ground to improve the soil's load-bearing capacity and liquefaction resistance.
Subsidence	Downward movement of the ground surface – terminology usually associated with widespread effects rather than localised settlement issues.
Syncline Fold	A geological fold with the younger rocks in its core, typically a downward fold unless it has been overturned.
Thrust Faulting	A type of fault where there has been relative movement of rocks of lower stratigraphic position which are pushed up and over rocks of higher stratigraphic position.
Translational Landslide	A landslide which moves downslope along a distinctive planar or slightly undulating surface of weakness i.e. fault, joints, bedding planes or the contact between rock and residual or transported soils.
Unsuitable Material	Material that is either organic material (other than topsoil), sourced from within cuts or fill areas, or material that by its inherent nature cannot be satisfactorily or economically reconditioned by wetting and drying for use as suitable (engineered) fill.
Wetland	Vegetated stormwater treatment device designed to remove a range of contaminants, providing superior water quality treatment to wetponds with increased filtering and biological treatment performance.
Wick Drain	Ground improvement technique to encourage dissipation of pore pressures under fill embankments. Wick drains accelerate settlements and reduce the time for safe construction of embankments on soft ground.

Contents

1. Introduction

This report forms part of a suite of technical reports prepared for the NZ Transport Agency's (NZTA's) Ara Tūhono Pūhoi to Wellsford Road of National Significance (RoNS) Puhoi to Warkworth section (the Project). Its purpose is to inform the Assessment of Environmental Effects (AEE) and to support the resource consent applications and Notices of Requirement for the Project.

The indicative alignment shown on the Project drawings has been developed through a series of multi-disciplinary specialist studies and refinement. A NZTA scheme assessment phase was completed in 2010, and further design changes have been adopted throughout the AEE assessment process for the Project in response to a range of construction and environmental considerations.

It is anticipated that the final alignment will be refined and confirmed at the detailed design stage through conditions and outline plans of works. For that reason, this appraisal has addressed the actual and potential effects arising from the indicative alignment, and covers the proposed designation boundary area. Except as noted in this report:

- We consider that the sites we have selected for surveys and testing are generally representative of all areas within the proposed designation boundary; and
- The geotechnical design solutions we recommend are likely to be applicable to other similar areas within the proposed designation boundary, subject to confirmation of their suitability at the detailed design stage.

We consider that the scope of the investigations and the appraisal contained in this report provides a broad understanding of the geotechnical conditions and provides sufficient information to support the consenting process. The models and detailed designs will be developed further as the knowledge and understanding of the ground conditions and its impact on the Project evolves during future design stages.

The purpose of the Geotechnical Engineering Appraisal Report is to:

a) Communicate the key engineering geological findings from our desk-based study and limited field geotechnical investigations;

b) Communicate any significant geological hazards and their geotechnical implications;

c) Communicate the main geotechnical implications of the significant earthworks required for the Project;

d) Outline the basis of the design elements in relation to the precedent set by similar schemes in similar environmental and geotechnical conditions;

e) Summarise the approaches we have made to minimise the geotechnical risks and potential adverse impacts on the environment through the development and assessment of design elements; and

f) Present recommendations for appropriate geotechnical design solutions that could be adopted in the implementation of the Project.

Many aspects of the geology and geotechnical conditions in this type of terrain have a bearing on the environmental effects of the Project. Our geotechnical engineering design and appraisal has been used to regularly inform other specialists in the Project of the geotechnical components so they can fully understand and assess the effects of constructing this Project in this terrain.

The structure and content of this report is as follows:

- Section 1 – Sets out the purpose and content of this report.
- Section 2 – Describes the indicative alignment and introduces the main geotechnical engineering elements of the Project.
- Section 3 – Outlines the general methodology of the geotechnical assessment, including geotechnical investigations and design.
- Section 4 – Summarises the general geology and geological hazards anticipated in the Project region.
- Section 5 – Describes the geological conditions identified along the route and the engineering geological models developed to form the basis of geotechnical design.
- Section 6 – Presents the geotechnical design criteria anticipated for the Project and the criteria adopted for our appraisal.
- Sections 7 to 12 – Describe our assessment of the main geotechnical elements and hazards that inform the Assessment of Environmental Effects. The main geotechnical elements include cut slopes, embankments, landslides, foundations, general earthworks properties and spoil disposal.
- Section 13 – Summarises our assessment of ground settlement in response to the Project.
- Sections 14 and 15 – Summarise the key elements of geotechnical risk and opportunity for the Project and present strategies and recommendations for minimising further risks and adverse effects.
- Section 16 – Lists the key references and documents used to support this report.

2. Project description

2.1 Background

This Project description provides the context for this appraisal. Sections 5 and 6 of the Assessment of Environment Effects (Volume 2) further describe the construction and operational aspects of the Project and should be relied upon as a full description of the Project.

The Government has identified Ara Tūhono Pūhoi to Wellsford as a Road of National Significance (RoNS), and the Project comprises a section of the Pūhoi to Wellsford route.

The Project realigns the existing SH1 from the Northern Gateway Toll Road (NGTR) at the Johnstone's Hill tunnels and joins back in to the existing SH1 just north of Warkworth. The indicative alignment will bypass Warkworth on the western side and tie into the existing SH1 north of Warkworth. It will be a total of 18.5 km in length. The upgrade will be a new four-lane dual carriageway road, designed and constructed to motorway standards and the NZTA RoNS standards.

2.2 Project features

Subject to further refinements at the detailed design stage, key features of the Project based on the indicative alignment and proposed designation boundary shown on the Project drawings are:

- Four lane dual carriageway (two lanes in each direction with a median and barrier dividing oncoming lanes);
- A connection with the existing NGTR at the Project's southern extent;
- A half diamond interchange providing a northbound off-ramp at Pūhoi Road and a southbound on-ramp from existing SH1 just south of Pūhoi;
- A western bypass of Warkworth;
- A roundabout at the Project's northern extent, just south of Kaipara Flats Road to tie-in to the existing SH1 north of Warkworth and provide connections north to Wellsford and Whangarei;
- Construction of seven large viaducts, five bridges (largely underpasses or overpasses and one flood bridge), and 40 culverts in two drainage catchments: the Pūhoi River catchment and the Mahurangi River catchment;
- A predicted volume of earthworks being approximately 8M m^3 cut and 6.2M m^3 fill within an area of approximately 189ha earthworks; and
- Removal of approximately 83.5ha of trees, comprising predominantly plantation pine and approximately 4ha of native bush.

The existing single northbound lane from Waiwera Viaduct and through the tunnel at Johnstone's Hill will be remarked to be two lanes. This design fully realises the design potential of the Johnstone's Hill tunnels.

The current southbound tie-in from the existing SH1 to the Hibiscus Coast Highway will be remarked to provide two-way traffic (northbound and southbound), maintaining an alternative route to the NGTR. The existing northbound tie-in will be closed to public traffic as it will no longer be necessary.

2.3 Route description by Sector

For assessment and communication purposes, the indicative alignment has been split into six sectors, as shown in Figure 1 and Drawing GT-200. The sectors are briefly described below:

2.3.1 Pūhoi Sector

The Pūhoi Sector extends from the northern portals of the Johnstone's Hill tunnels to the vegetated escarpment north of Pūhoi Road. Key features of this Sector are:

- Approximately 2.4km in length;
- The indicative alignment passes east of Pūhoi village and west of SH1;
- Two viaduct structures: Okahu Viaduct(crossing Okahu Creek) and Pūhoi Viaduct (crossing the Pūhoi River and Pūhoi Road);
- The indicative alignment passes across the Coastal Marine Area at Okahu Creek;
- A 45m long retaining wall to the west of the northbound carriageway;
- Northbound off-ramp at Pūhoi Road and southbound on-ramp from existing SH1;
- Predominantly rural land use with residential settlement west being part of Pūhoi village;
- A southern tie-in to Johnstone's Hill tunnels; and
- A connection between the Hibiscus Coast Highway and existing SH1 in both directions.

The geology of this sector predominantly comprises Pakiri Formation in the hills and Quaternary-age alluvium and estuarine soils surrounding the Pūhoi River and Okahu Creek. The key geotechnical elements of this sector are illustrated on Drawing GT-201 to GT-203. They are:

- Ch 64620-64850: The indicative alignment will interact with existing slope stabilisation measures in place on the eastern side of southbound carriageway including a mechanically stabilised earth (MSE) embankment, shear piles and existing retaining walls. Similar combinations of shear piles, anchors and MSE embankments are likely to be required for the new alignment. A large amount of ground investigation data exists for the southern connection of the Project as a result of the detailed investigations for the NGTR construction.
- Ch 64000-64300: Multiple shallow and deep-seated landslides in the Billing Road area will need to be accommodated for in the design of the cuts, piers and the Okahu Viaduct northern abutment.
- Ch 64020-64070: A 45m long retaining wall to the west of the northbound carriageway to prevent earthworks imposing on a rediscovered pa site.
- Ch 63780-63900, Ch 63540-63630 and Ch 62900-63090: Soft alluvium crossed by large embankments will require ground treatment.
- Ch 63110-63500: Large block landslide inferred at Pūhoi southbound on-ramp is intercepted by cut slopes.
- Ch 62940-63160: Shallow earth slides, flows and alluvium crossed by an embankment.
- Foundations for the Okahu and Pūhoi Viaducts.

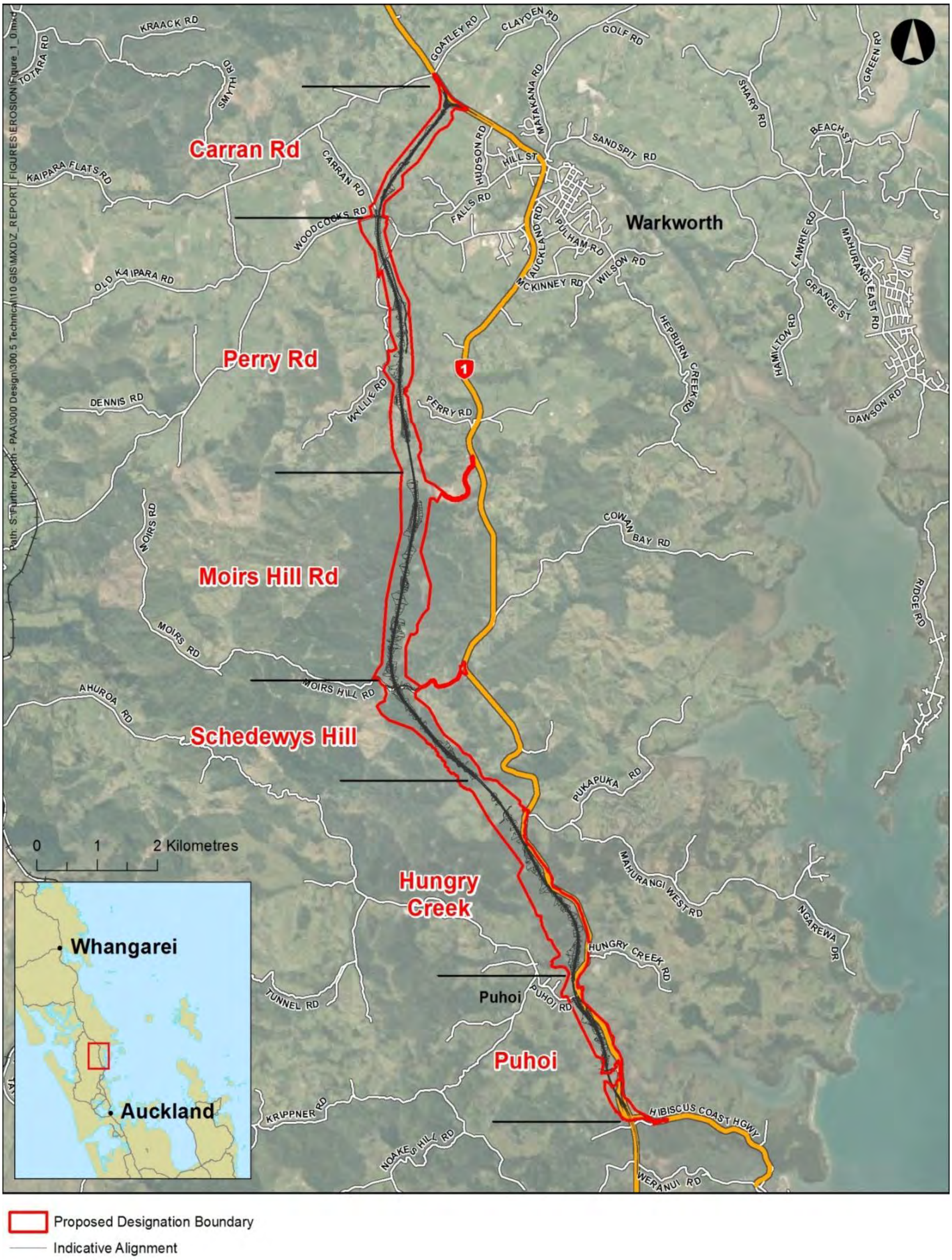


Figure 1: Project sectors

2.3.2 Hungry Creek Sector

This sector is illustrated on Drawings GT-203 – GT-206.

The Hungry Creek Sector extends from the vegetated escarpment north of Pūhoi Road to Schedewys Hill. Key features of this sector are:

- Approximately 3.8km in length;
- The indicative alignment runs largely parallel to and west of SH1;
- An overpass where the indicative alignment passes over Watson Road (a private forestry road);
- One viaduct structure, Hikauae Viaduct (crossing Hikauae Creek); and
- Plantation forestry with some open grazing land and scattered rural-residential settlement.

The geology of this sector is shown on Drawing. GT-131 – GT-132 and predominantly comprises Pakiri Formation with Northland Allochthon material at its northern end around Mahurangi West Road.

The key geotechnical elements in this sector are:

- Ch 61940-62540: deep cut with maximum cut slope height of approximately 50m;
- Ch 60770-61890: Several valleys with alluvium crossed by large embankments requiring alluvium to be removed/treated and shear keys in excavated into competent rock;
- Ch 60920-61160: A mechanically stabilised earth (MSE) slope close to SH1 in the vicinity of Hungry Creek Arts School;
- Ch 60280-60740: Watson Road cut, maximum cut slope height of about 50m;
- Ch 60020-60280: A MSE slope and embedded concrete retaining wall about 100m long and 10m height north of Watson Road;
- Ch 59560: Cuts for the main indicative alignment and Hikauae access track realignment in Northland Allochthon materials;
- Ch 59200-59400: Cuttings, embankments, viaduct piers and abutments (Hikaue Viaduct and Schedewys Viaduct) formed in Northland Allochthon material;
- Ch 59200: Stormwater wetland on Northland Allochthon material.

2.3.3 Schedewys Hill Sector

This sector is illustrated on Drawings GT-206 – GT-207.

The Schedewys Hill Sector extends from Schedewys Hill (just south of the SH1/Mahurangi West Road intersection) to Moirs Hill Road. Key features of this sector are:

- Approximately 2km in length;
- The indicative alignment passes to the west of SH1;
- One large viaduct structure, Schedewys Viaduct, with split level carriageway;
- Mostly plantation forestry with a small area of open pasture land to the south and some scattered rural-residential settlement at the northern extent of the sector, off Moirs Hill Road; and

- Moirs Hill Road is the catchment divide between the Pūhoi and Mahurangi catchments.

The geology of this sector is shown on Drawing GT-132 and predominately comprises steep elevated terrain of the Pakiri Formation.

The key geotechnical elements in this sector are:

- Foundations for Schedewys Viaduct piers and abutments
- Ch 58330-58710: MSE embankments in steep ground
- Ch 57900-58400: Wreaks Road cut – maximum cut slope height of approximately 45m.
- Ch 57060-57500: Wreaks Road embankment – potential presence of Northland Allochthon.
- Ch 56800-57140: Moirs Hill Road south cut – maximum cut slope height of approximately 45m.

2.3.4 Moirs Hill Road Sector

This sector is illustrated on Drawing GT-208 – GT-210. The Moirs Hill Road Sector extends from Moirs Hill Road through to just south of Perry Road. Key features of this sector are:

- Approximately 3.2km in length;
- The indicative alignment passes to the west of SH1, skirting the western edge of the Pohuehue Scenic Reserve;
- Realignment of Moirs Hill Road;
- An underpass where the indicative alignment passes beneath Moirs Hill Road; and
- Mostly plantation forestry with a small area of open pasture land at the northern extent of the sector.

The geology of this sector is shown on Drawing GT-132 and predominantly comprises Pakiri Formation.

The key geotechnical elements in this sector are:

- Moirs Hill Road re-alignment – widening and straightening requiring small fill retaining walls on steep slopes or existing small landslides.
- Ch 56870: Foundations for Moirs Hill Road underpass.
- Ch 56420-56760: Moirs Hill North cut – deep box cut in deep weathering profile, maximum cut slope height approximately 50m.
- Ch 55720-56110: Mahurangi Road cut – deep box cut, maximum cut slope height about 60m.
- Ch 55300-55720: Mahurangi embankment – large embankment with slope height in order of 45m.
- Ch 54540-55060: Redwoods Road embankment – large embankment with slope height in order of 50m.
- Ch 53820-54540: Redwoods Road cut – deep box cut, maximum cut slope height approximately 55m.
- Ch 53560-53830: Perry Road embankment and south abutment of Perry Road Viaduct – maximum slope height approximately 30m.

2.3.5 Perry Road Sector

This sector is illustrated on Drawing GT-211 – GT-213.

The Perry Road Sector extends from just south of Perry Road to the Woodcocks Road / Carran Road intersection. Key features of this sector are:

- Approximately 4.4km in length;
- The indicative alignment continues to the west of SH1, passing west of Genesis Aquaculture;
- An overpass where the indicative alignment passes over Wyllie Road;
- Two viaduct structures: Perry Road Viaduct and Kauri Eco Viaduct (crossing the Mahurangi River (Right Branch);
- At Wyllie Road the indicative alignment crosses the Vector Limited High Pressure Gas Transmission Line connection to Warkworth;
- Realignment of a section of Woodcocks Road and the private access road connection to Wyllie Road; and
- Predominantly rural with areas of rural-residential development at Perry Road, Wyllie Road and Woodcocks Road.

The geology of this sector is shown on Drawings GT-132 – GT-133 and generally comprises Pakiri Formation in the south and isolated elevated Pakiri Formation hills separated by wide flat valley floors of alluvial deposits surrounding Warkworth township. Pockets of Mahurangi Limestone (Northland Allochthon material) are encountered north of Woodcocks Road and at the northern termination of the Project.

The key geotechnical elements in this sector are:

- Foundations for piers and abutments for the Perry Road Viaduct and Kauri Eco Viaduct.
- Ch 52800-52960: Embankment and cut intercepting Perry Road landslide on the northern valley side.
- Ch 52360-52580: Embankment aligned over a landslide and requiring stabilisation.
- Ch 52170-52340: Large embankment over alluvium. Ground treatment below embankment maybe required (for example deep soil mixing, stone columns or piles).
- Ch 51720-51820: Wyllie Road landslide. Cuts into landslide complex with deep-seated block failures in main landslide body.
- Ch 50860, Ch 51020, Ch 51340, Ch 51590: Alluvium below proposed embankments may need to be removed / treated.
- Ch 50000-50560: Wyllie Road south embankment and Wyllie Road to Woodcocks Road embankment. Ground treatment (e.g. deep soil mixing) may be required below embankment.

2.3.6 Carran Road Sector

This sector is illustrated on Drawings GT-214 – GT-215. The Carran Road Sector extends from the Woodcocks Road / Carran Road intersection to the northern extent of the indicative alignment at existing SH1 just south of Kaipara Flats Road. Key features of this sector are:

- Approximately 2.7km in length;

- The indicative alignment extends to the west of SH1, turning east to the SH1 northern tie-in;
- Termination of the motorway at a new roundabout at SH1;
- One large viaduct structure, Woodcocks Road Viaduct (crossing the Woodcocks Road / Carran Road intersection and the Left Branch of the Mahurangi River);
- One structure, the Carran Road Flood Bridge, to provide for the passage of floodwater in a 100 year flood event and farm access;
- A farm track underpass; and
- Predominantly farmland used for pastoral grazing with lifestyle blocks around Carran Road and a lifestyle subdivision at Viv Davie-Martin Drive.

The geology of this sector is shown on Drawing GT-133 and comprises a combination of Pakiri Formation, alluvial/colluvium deposits and Northland Allochthon.

The key geotechnical elements in this sector are:

- Ch 48550-49050: Carran Road landslides. Four landslides in close vicinity of the proposed cuttings, embankments and abutment.
- Ch 48000-48660: Carran Road embankment. Ground treatment may be required below embankment
- Ch 47100-48000: Undercutting of alluvium where encountered.
- Foundations for the Carran Road Flood Bridge and Woodcocks Road viaduct.

2.4 Interchanges and tie-in points

The Project includes one main interchange and two tie-in points to the existing SH1, namely:

- The Pūhoi Interchange;
- Southern tie-in where the indicative alignment will connect with the existing NGTR; and
- Northern tie-in where the indicative alignment will terminate at a roundabout providing a connection with the existing SH1, just south of Kaipara Flats Road north of Warkworth.

3. Methodology

3.1 Summary of methodology

We have adopted the following approach for this appraisal:

- Collate and review existing information available on the geology and geotechnical conditions within and around the Project area from desktop studies, field mapping and site investigations;
- Prepare preliminary engineering geological and geotechnical models for the project area based on the existing knowledge of the groundwater and geology of the Project area, and identify the specific geohazards that may impact on the Project;
- Carry out preliminary geotechnical investigations of the main geotechnical and hydrogeological aspects of the Project that potentially have an effect on the environment;
- Further develop the engineering geological model and refine as information and data is accumulated;
- Have input to and review the general arrangement of the Project design including main structures and vertical and horizontal indicative alignments;
- Consider geotechnical issues associated with the likely construction sequencing and temporary works required for the construction of the Project;
- Assess how the Project interacts with the ground conditions (for both construction and long term operations) based on the engineering geological model and through the development of feasible design solutions;
- Improve and develop the road design concepts and geotechnical elements in close collaboration with other design and environmental specialists;
- Using experience from the design and construction of other major highway projects within the general region of the Project – (including the design, construction and maintenance of the existing SH1 between Pūhoi and Wellsford) – determine the potential effects of the likely construction activities and the long-term operation of the Project; and
- Derive a range of potential measures that would avoid, remedy or mitigate actual and potential geotechnical effects of the Project.

3.2 Engineering geological mapping and geotechnical appraisals

3.2.1 Previous geotechnical appraisal reports

An initial desk-top review and reconnaissance mapping of the geological and geotechnical conditions over the broader study area was conducted as part of the early scoping phase of the Pūhoi to Wellsford RoNS Project between March and April 2010. This work is presented in a Preliminary Geotechnical and Geological Appraisal Report (PGGAR) (SKM 2010) for the Project.

The PGGAR provided geotechnical information to assist in the early route selection process during the Project's scoping phase. It included information on:

- Regional and local geological setting;
- Regional geo-hazards including faults, seismicity and landsliding;

- Local geology including stratigraphy, distribution and engineering geological aspects;
- Significant geo-hazards identified in the vicinity of the long-list of alignment options;
- Engineering geological and geotechnical considerations including material resources for earthworks; and
- Approaches and recommendations for geotechnical investigations for scheme assessment and preliminary design.

The reconnaissance mapping was restricted to the existing SH1 corridor, local side roads and publically accessible land.

Following completion of the PGGAR activities, route options were short-listed for further development and assessment. Subsequently, additional field appraisals and qualitative assessments were carried out in late 2010, focussing on the short-listed options and several additional relatively localised sub-alignments which were under consideration. The second phase of mapping work included considerably more observations in areas more remote from local roads and publicly accessible land where property access was not possible in the earlier studies.

The additional work completed in late 2010 identified specific key geo-hazard and geotechnical features along each of the short-listed alignment options and assigned qualitative hazard ratings for the purposes of route comparison only. The hazard ratings were largely based on:

- Potential construction issues;
- The anticipated scale of investigation and geotechnical design challenges;
- The ability to avoid or reduce the impact of the feature on the short-listed alignment and surrounding environment by local vertical or horizontal re-alignment;
- The long-term risk to the RoNS following construction; and
- The security of the existing SH1.

Based on the above information, a qualitative assessment for each of the short-listed options was completed which was used in the options evaluation and route selection stage of the scheme assessment process.

3.2.2 Geotechnical desk studies

SKM completed initial desk studies of the Project area during the earlier scheme assessment and route selection phase of the Project. This information was initially summarised in the PGGAR.

This appraisal has also included the review of additional data and documentation relevant to the Project that has been collated since the scheme assessment. In summary, the many data sets used for this appraisal from both phases include:

- Published geological maps and bulletins;
- Geological and geotechnical publications (journal papers);
- Unpublished university theses;
- Data sets held by Auckland Regional Council and Rodney District Council (now both Auckland Council);
- SH1 maintenance records, reports and site registers from the NZTA and Auckland Motorways Alliance; and

- Geotechnical design construction drawings and reports for similar engineering projects including the Albany to Pūhoi Realignment (ALPURT) and NGTR sections of the Auckland Northern Motorway.

3.2.3 Aerial photograph interpretation (API)

Throughout the earlier route selection and scheme assessment phases SKM completed an aerial photograph interpretation (API) of the wider area and the Project corridor using several sets of historical aerial photographs of differing scales and timeframes. An API involves reviewing aerial photographs which have a roughly 60% overlap between adjacent frames with a mirror stereoscope to provide stereo image coverage. In this manner it is possible to identify the principal engineering geological and geomorphic features such as active or relic landslides that demand further inspection and verification in the field.

The Further North Alliance has also completed supplementary API for this appraisal to identify potential spoil disposal areas and key features of geological interest on the indicative alignment such as large landslides or unstable terrain. The API was regularly reviewed as additional mapping and ground investigations were completed. The implications of these features have been considered during the development of the concept designs for the Project.

3.2.4 Digital elevation model evaluation

High resolution digital elevation models (DEMs) are useful in the recognition of landforms, including fault lines and major landslide features. A DEM with a grid size of 2m was created from the Auckland Council LiDAR[1] data set. Various sets of hill-shade models were developed, producing 3D 'pseudo' images of the landscape with varying sun illumination and shadowing effects. The hill-shade models were examined and regularly used to support interpretations from the API work and field observations.

3.2.5 Engineering geological mapping

The resultant maps and knowledge held by the Project team from the initial scoping and scheme assessment mapping work formed the initial basis for this appraisal. The Project team have also recently carried out additional engineering and geological mapping and inspections along the indicative alignment to further contribute to the development of the geotechnical understanding and project design. A particular focus for the additional mapping fieldwork has been where local route realignments and potential spoil disposal areas were under consideration. The field engineering geological appraisal maps are presented in Drawings GT-100 to GT-117.

3.3 Intrusive geotechnical investigations

3.3.1 Preliminary geotechnical investigations (Stage 1)

SKM carried out a preliminary geotechnical investigation at discrete locations within the Project area in January and February 2011, herein referred to as the 'Stage 1' geotechnical investigation. The results from the Stage 1 investigation are included in the Preliminary Geotechnical Investigation Factual Report (SKM, 2011).

The Stage 1 geotechnical investigation was not intended to be a comprehensive geotechnical investigation suitable for detailed design. Rather, it was scoped to verify and to provide a better

[1] Light Detection and Ranging

understanding of significant geotechnical hazards and uncertainties along the Project alignment at critical locations (such as large landslide locations). The Project alignment remains largely similar since these investigations.

The scope of the Stage 1 geotechnical investigation comprised:

- A total of fourteen machine boreholes (the '100' series boreholes), principally targeted at the key landslide locations and at several of the deepest cuts.
- Standard penetration testing at regular intervals in the majority of boreholes to aid assessment of in situ strength.
- Logging and description of material encountered in line with NZ Geotechnical Society guidelines (NZGS, 2005).
- A total of six test pits in Northland Allochthon material and alluvial deposits.
- Optical televiewer imaging of the open borehole walls to survey the conditions of the soil/rock mass at depth in the boreholes.
- A small selection of laboratory testing to provide strength characteristics and soil classifications.

Figure 2 summarises the investigation locations. Drawings GT-201 to GT-215 also display the Stage 1 investigation locations in more detail.

No piezometers (instruments installed in the ground to accurately measure groundwater levels) were installed and groundwater monitoring was not completed due to constraints posed by land ownership and ongoing legal access for monitoring at the time of the investigations.

3.3.2 Stage 2 geotechnical investigations

To further advance the geotechnical assessment, the Project Team completed a 'Stage 2' geotechnical investigation between February and April 2013 (Further North Alliance, 2013). The scope of the Stage 2 geotechnical investigation comprised:

- A total of twenty-six machine boreholes (the '200' series boreholes) comprising six PQ sized (123mm diameter) and twenty HQ sized boreholes (96mm diameter).
- Seventeen Cone Penetration Tests (CPTs) with selected test measurements of pore pressure dissipation.
- Standard penetration testing at regular intervals in the majority of boreholes at appropriate intervals.
- Logging and description of material encountered in accordance with the NZ Geotechnical Society Guidelines (NZGS, 2005).
- Optical televiewer imaging of the open borehole walls to survey the soil/rock mass conditions at depth in the boreholes.
- Installation of both single and nested standpipe piezometers and monitoring of groundwater levels.
- Geotechnical laboratory testing of disturbed and undisturbed core samples.
- Packer testing of significant fracture zones where identified below the groundwater table.

Figure 2 summarises the Stage 2 investigation locations. Drawings GT-201 to GT-215 also display the Stage 1 investigation locations in more detail.

The Stage 2 investigation was scoped to investigate the main geotechnical and hydrogeological aspects of the Project which potentially have an effect on the environment. The factual data obtained from the investigation is reported in the Stage 2 Geotechnical Investigation Factual Report.

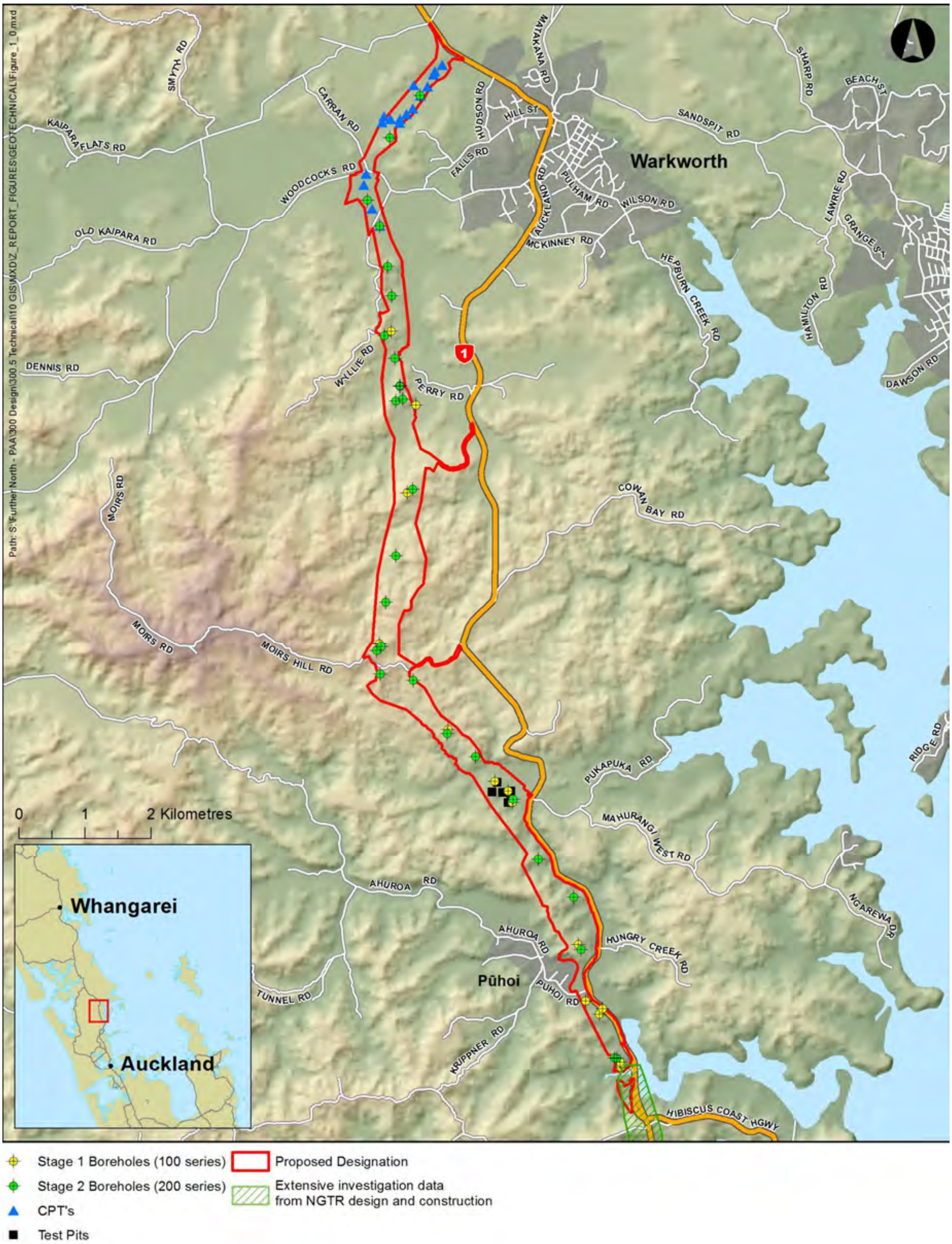


Figure 2 Overview of Geotechnical Investigations

3.4 Geotechnical laboratory testing

The Stage 1 and Stage 2 geotechnical investigations included a programme of laboratory testing to determine the properties of the materials encountered along the route.

Laboratory testing was carried out in accordance with New Zealand Standard NZS 4402:1986 (Methods of testing soils for Civil Engineering purposes) by an International Accreditation New Zealand accredited geotechnical laboratory operated by Opus International Consultants Limited. The laboratory testing results are also included in the Stage 1 and Stage 2 Geotechnical Factual Reports.

The testing undertaken on selected soil and rock samples to date can be broadly divided into the following categories:

- Basic Index Testing - Moisture Content, Atterberg Limits (Liquid Limit and Plastic Limit), Particle Size Distribution (by wet sieving and hydrometer method) and Organic Content.
- Soil Strength - Consolidated Undrained Triaxial Shear Strength.
- Soil Compressibility - One dimensional consolidation (oedometer).
- Rock Strength - Unconfined Compressive Strength (UCS) (with modulus).

As a supplement to the Project-specific data, for the geotechnical appraisal, the Project Team has obtained and made use of the comprehensive laboratory test results from the detailed design and construction stages of the Northern Gateway Toll Road (Northern Gateway Alliance (NGA), 2008a) and previous investigations of improvements and realignments of SH1 in the vicinity of Schedewys Hill (Opus, 2002). Both sets of investigation results include tests of similar geological materials in close proximity to the Project and in similar terrain.

3.5 Engineering geological model

The Project Team has developed an engineering geological model of the indicative alignment for this appraisal based on the work to date summarised in Section 3.1. The model supports the assessment of the ground conditions and has been used to:

a) Inform the geotechnical analyses;

b) Improve the indicative alignment during the design process; and

c) Communicate the ground conditions to the wider Project team.

This model will be reviewed and developed further during future stages of the Project as new geotechnical information is generated. Detailed designs based on detailed investigations and ground models which are more site-specific will be generated prior to construction.

3.6 Analytical modelling

The Project Team has carried out basic geotechnical modelling and analysis of key design elements for this appraisal, such as large embankments, cut slopes, ground improvement and retaining structures. Analytical modelling is largely limited to slope stability analyses of the key earthworks and design features that were considered to have potentially greater environmental effects. This appraisal has included slope stability analyses of the elements with highest loads or deepest excavations to verify that the conceptual designs, based on experience and precedence from other similar projects, can be constructed within the proposed designation footprint to an appropriate design and performance criteria.

The modelling is limited by the available geotechnical information to the use of generic ground models and shear strength characteristics for each of the principal geological ground types: Pakiri Formation, Alluvium and Northland Allochthon.

The stability assessments are based on limit equilibrium analyses of both circular and non-circular failure mechanisms for short term (end of construction) and long term (in service) conditions. Appropriate seismic design cases have also been considered for all analytical models.

Further details on the geotechnical modelling of design elements are discussed in Sections 6 to 12.

4. Existing environment – geology and geomorphology

4.1 Regional geology and geomorphology

A geological map (Figure 3 and Drawings GT-131 to GT-133) has been produced based on the published geological maps (e.g. Edbrooke, 2001) and modified to include the results of the aerial photograph interpretation, geological mapping and intrusive investigations carried out for this Project.

The majority of the Project area is underlain by sedimentary rocks of the Waitemata Group that were deposited in a deep marine basin approximately 15 to 21 million years ago.

In the Project area the Tertiary age Waitemata Group rocks comprise regular alternating layers (beds) of very weak to moderately strong volcaniclastic sandstone and siltstone of the Pakiri Formation. The Pakiri Formation forms the majority of the steep rugged topography found in the Project area. Occasional harder beds of strong coarse-grained andesitic conglomerates and submarine mass flow deposits of re-welded volcanic debris (coarse volcaniclastic grit/conglomerate) are also present within the Pakiri Formation.

Also present within the Project area are rocks of the Northland Allochthon. The Northland Allochthon rocks are older than the Waitemata Group and were initially formed about 21 to >65 million years ago. They were then transported and emplaced towards the south or south west into the deepening Waitemata Basin from approximately 21 million years ago by a complex process of faulting and submarine landsliding at the same time as the Pakiri Formation was being deposited. Consequently, the Northland Allochthon rocks are severely deformed, crushed and sheared (Winkler, 2003). The above mentioned geological processes have resulted in a complex arrangement and juxtaposition of Waitemata Group rocks with large lenses or disrupted slices of significantly weaker, highly sheared mudstones, siltstones, sandstones and limestones of the Northland Allochthon (Isaac, Herzer, Brook, & Haywood, 1994).

Along the indicative alignment the Northland Allochthon rocks generally comprise undifferentiated rocks of the Mangakahia Complex (primarily sheared mudstone). Mahurangi Limestone of the Motatau Complex is mapped at the northern termination of the Project. Small serpentinite bodies may also be present in the area but known bodies have been quarried out (Rait, 2000).

Over time major rivers have eroded deep valleys into the landscape many of which were 'drowned' and in-filled with sediments as a result of sea level rises since the last ice age. These drowned valleys dominate the east coast of Northland including the Pūhoi, Mahurangi and Warkworth valleys. These valleys are in-filled with deep, soft estuarine and alluvial sediments but remnants of raised terrace levels representing previous higher sea levels or lower land levels are also present (Ballance & Williams, 1992).

Colluvium (sediments resulting from slope movement or downhill creep) is present on the hillsides and has accumulated near the base of many slopes. This slope movement is a natural process of landscape evolution but has been exacerbated as a result of human impacts on the landscape since the 1820s including the changing land-use from kauri forest to scrub, pasture or urban land (Ballance & Williams, 1992).

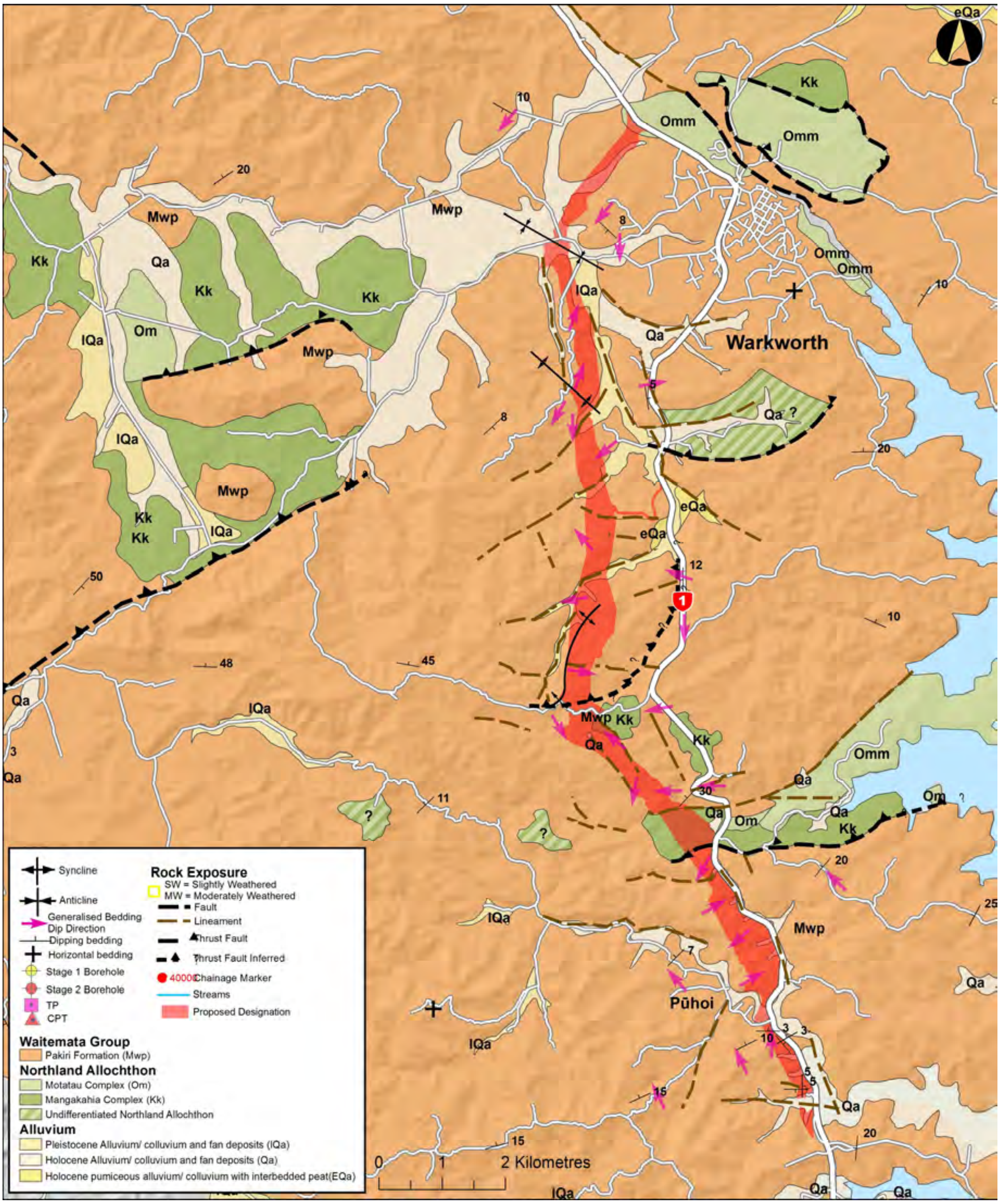


Figure 3: Summary Geological Map

4.2 Geological structure

The main regional geological structures are inactive thrust faults defining many of the main boundaries between the Pakiri Formation and large Northland Allochthon bodies. This schematic relationship is shown in Figure 4. Within the Northland Allochthon materials the sequential emplacement of thrust sheets has resulted in large scale fold structures with the possibility that older materials now overlie younger deposits and rock formations that have been completely overturned. Smaller blocks of highly deformed Pakiri Formation rocks have also been reported within the Northland Allochthon units in the Auckland Region (Tonkin & Taylor, 2004).

Syn- and post-depositional faults and folds have also resulted in additional and often complex local deformation of the rocks in the area (e.g. Figure 5).

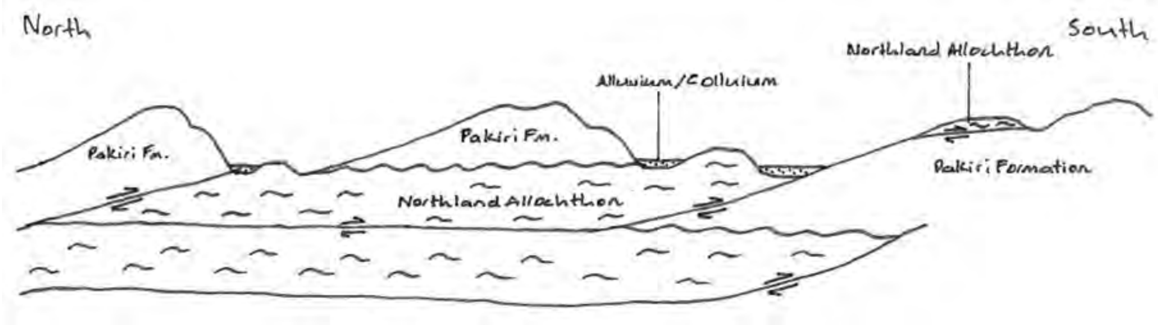


Figure 4: Simplified, inferred geological relationships within the Pūhoi to Warkworth section, adapted from Issac et al. (1994) and Edbrooke (2001).

Figure 5: Tight folds in the Pakiri Formation rocks exposed near Billing Road (Pūhoi Sector).

Only one main fault has been identified on the published geological map in the vicinity of the indicative alignment (Edbrooke, 2001). This is an east-west orientated thrust fault along the southern margin of the Schedewys valley.

Several main topographic lineaments are also recognised based on the indicative alignment of streams, linear gullies and other topographic features. These may reflect preferential erosion along weaker crushed or sheared rock marking significant fault zones. These are shown on Figure 3 and Drawings GT-131 to GT-133, together with the published fault listed above.

The geological structure is the dominant mechanism controlling slope stability and hence the current topography is largely controlled by the underlying geological structure. The main ridgelines are often formed by anticline (^ shaped) folds and the main valleys often reflect the axes of syncline (v shaped) folds.

The layered Pakiri Formation rocks, which form the surface geology across the majority of the site, have few distinct marker beds making it difficult to correlate the rocks across the area and recognise large-scale geological structures. Similarly, the Northland Allochthon rocks are typically highly sheared and closely fractured, thus have little discernible structure. In addition, long-continued weathering in a warm, moist climate on rocks that are rich in easily altered minerals has caused most of the rocks to weather deeply. The result being that the geological sequences and geological structure (such as the orientation of faults, folds, and bedding) are difficult to decipher from surface exposures.

Despite this, observations of the general bedding orientations collected to date from a combination of outcrop exposures and interpretations from the optical televiewer data obtained from the borehole investigations are shown on the geological map (Drawings GT-131 to GT-133). Whilst the bedding is typically gently inclined (0° to 30°) the detailed geological mapping has shown that in places the Pakiri Formation rocks are locally exposed as a number of tight folds.

4.3 Areas of geological significance

A search of the online New Zealand Geo-Preservation Inventory identified one location of recorded geological significance in the area surrounding the Pūhoi to Warkworth Project (NZGI, 2010).

The Wilson's Cement Works are remnants of the old lime and cement works on the banks of the Mahurangi River, south of Warkworth. It is located over 4km east of the proposed designation and would not be affected by the Project.

5. Engineering geology and geological hazards

5.1 The engineering geological model

The engineering geological model is summarised by a geological long section of the indicative alignment included as Drawings GT-151 to GT-161. Note the long section has a five times vertical exaggeration.

The ground conditions encountered along the indicative alignment typically comprise Pakiri Formation (regular alternating beds of sandstone and siltstone). Alluvium and colluvium soil deposits are present in low lying regions and valleys. Pervasively sheared Northland Allochthon mudstone/siltstone is identified in the Schedewys valley at the northern end of the Hungry Creek Sector and capping the ridgeline near Moirs Hill Road in the Schedewys Hill Sector.

The following sections summarise the geological models, material descriptions and geotechnical strength parameters adopted for the geotechnical appraisal and concept designs. Where shown, the strength parameters are based on:

- Field observations and engineering judgement.
- Previous experience with these materials and parameters adopted for similar materials in the Auckland Region where available.
- The Stage 1 and Stage 2 investigation and laboratory test data referred to in Section 3.4. Measured and interpreted material strengths used for detailed design of the NGTR section of the motorway immediately to the south of the Project.

The parameters represent typical values for the purposes of concept or outline design.

Laboratory tests were carried out on rock and soil samples recovered from the boreholes and trial pits, including soil classification and strength tests. The detailed test results are included in the Geotechnical Factual Reports. Summary graphs of some results are included in Appendix A.

5.2 Pakiri Formation

5.2.1 Rock mass properties

Exposures of the Pakiri Formation rocks can be seen in road cuts along the NGTR and existing SH1. The investigations show the Pakiri Formation along the Project length can comprise varying intervals of:

- thick beds of very weak to moderately strong sandstone ranging from 0.5 to 10m thick alternating with thinner weak siltstone beds (the formation is sandstone dominant);
- regular thin laminated siltstone beds alternating with fine grained sandstone beds (0.05-0.2m thick);
- thick sequences of siltstone with intermittent thick sandstone beds (siltstone dominant);

Bedding is predominantly sub-horizontal to gently inclined (5-10°) but displays evidence of broad structural folding. The field mapping and investigations suggest a series of gentle syncline and anticline folds. The inferred locations of the fold axes based on very limited data to date are shown on Drawings GT-131 to GT-133.

The fractures in the rock mass are tight or narrow in aperture and typically exhibit a slight undulation. The open fracture surfaces generally display a mineral coating of either manganese oxide or limonite where occurring above the groundwater level. Some highly fractured zones have been encountered in localised areas during the drilling. These zones may provide greater inflows or seepages of water and localised instability if exposed in excavations.

The Pakiri Formation rocks weather to pink, red or orange-brown soft to very stiff silty clays, clayey silts and sandy silts. The strongest red and pink hues typically indicate weathered soils derived from the more iron-rich highly volcaniclastic sandstones. Highly and moderately weathered rocks may be extremely weak to very weak (unconfined compressive strengths, UCS, of <1 to 5 MPa). Slightly weathered sandstones are often very weak to moderately strong (UCS of 5 to 30 MPa).

Volcaniclastic sandstones and conglomerates

Some thick, more cemented moderately strong sandstone and conglomerate beds that have a high content of volcanic material have been identified along the indicative alignment. These materials are generally massive (without internal bedding) and strongly contrast with the typically well bedded nature of the sandstones and siltstones. These beds are more resistant to erosion resulting in readily identifiable outcrops relative to the surrounding exposed “softer” Pakiri Formation materials. Where the volcaniclastic materials have been weathered to soils they may sometimes contain relatively strong ‘corestone’ boulders left within a surrounding soil mass.

The volcaniclastic conglomerates encountered along the indicative alignment to date typically range in thickness from 100mm discrete beds up to 2.5m thick layers (e.g. BH214 and BH215) and are moderately strong. General description varies from coarse sandstone with a trace of angular volcanic clasts, including basalt and andesite gravel-sized fragments (grit), through to a volcaniclastic conglomerate of sub-angular to sub-rounded volcanic clasts supported in a silt matrix.

Also often included in the grit beds are “rip-up clasts”, that are lumps of the surrounding Waitemata beds which have been ripped up and mobilised during the grit bed transportation.

These grits and conglomerates can have higher permeability than the interbedded sandstone/siltstone units of the Pakiri Formation and as such these beds provide transmissive zones for groundwater movement.

5.2.2 Overview of Pakiri Formation along the indicative alignment

The geotechnical investigation and mapping around the Billing Road location identified the Pakiri Formation to be sandstone dominated. Here the rocks are potentially fault controlled and deformed by tight folding, as seen exposed in a nearby cutting on the existing SH1. Mapping has also identified 2 - 3m thick beds of volcaniclastic conglomerate in the area.

From the Pūhoi River north to the Hikauae Viaduct, the Pakiri Formation appears to have a greater proportion of siltstone beds and is gently inclined towards the north.

Northwards from Schedewys Viaduct through to Moirs Hill Road, the Pakiri Formation is again sandstone dominated with localised occurrences of thick volcaniclastic conglomerate layers intercepted by the boreholes.

Mapping has shown thick, slightly weathered weak to moderately strong sandstone beds are exposed in the base of many stream channels along this section. Beds are typically inclined towards the north-west over this section.

Very deep weathering was observed just north of Moirs Hill Road (in BH213, BH214, and BH111) with soft soils and very weak rock extending to relatively greater depths than intercepted elsewhere. Whereas shallow weathering with a rapid transition from completely weathered into slightly weathered Pakiri Formation rock was encountered north of this location through to the Perry Road Viaduct.

Closely spaced inter-bedded sandstone and siltstone is found around the Perry Road area. A good example is exposed in the old US Army quarry site off Perry Road (refer to Figure 6). Occasional coarse sandstone / volcaniclastic grits are also present. The beds are very gently inclined towards the south-west in this area.

Boreholes in the cuts around Wyllie Road encountered slightly deeper weathering of the sandstone dominated Pakiri Formation.

From approximately Ch 50500 northwards to the northern connection with the existing SH1 much of the indicative alignment is located on alluvial deposits overlying the Pakiri Formation. Slightly weathered Pakiri Formation rocks are observed in some streams where erosion has removed the alluvium.

Figure 6: Closely bedded weak alternating sandstone and siltstone in the Perry Road area.

5.2.3 Pakiri Formation properties

Soil classification and strength tests results from the Pūhoi to Warkworth project investigations to date are summarised in Appendix A.

The Atterberg Limits test results show the majority of the residually and completely weathered Pakiri Formation soils from the geotechnical investigations along the indicative alignment are classified as silts and clays of high and very high plasticity.

The Project's soil classification test results are consistent with much larger soil classification data sets from the NGTR investigations immediately to the south, indicating the expected characteristics and soil behaviours for this Project are similar to the NGTR section. This observation supports the notion that the geotechnical design solutions adopted for dealing with the residual soils in the NGTR cuts and embankments to the south may also generally be applicable to this Project.

Table 1 summarises the strength properties adopted for the consent design.

Table 1: Pakiri Formation strength properties

Geological formation	Undrained shear strength	Effective strength		Unit Weight
	Su (kPa)	c' (kPa)	Ø' (deg)	(γ,kN/m3)
Residual Soil and Completely Weathered Pakiri Formation	40-100	5	28	18
Highly weathered Pakiri Formation	75 - 150	7	32	20
Moderately weathered Pakiri Formation	>150	40	35	23
Slightly weathered Pakiri Formation	-	200	40	23

5.3 Northland Allochthon

5.3.1 Overview

Northern Allochthon material will be traversed by the indicative road alignment through the Schedewys valley (north end of Hungry Creek Sector) and capping the ridge near Moirs Hill (Schedewys Hill Sector).

It is encountered in the Stage 1 and 2 geotechnical investigations as completely to moderately degraded (class V to class III respectively), dark brown to grey micro-fractured / sheared, slightly calcareous siltstone and has been interpreted as belonging to the Mangakahia Complex.

The typical Northland Allochthon ground profile is illustrated schematically in Figure 7 below. Table 2 also provides further description of the engineering characteristics.

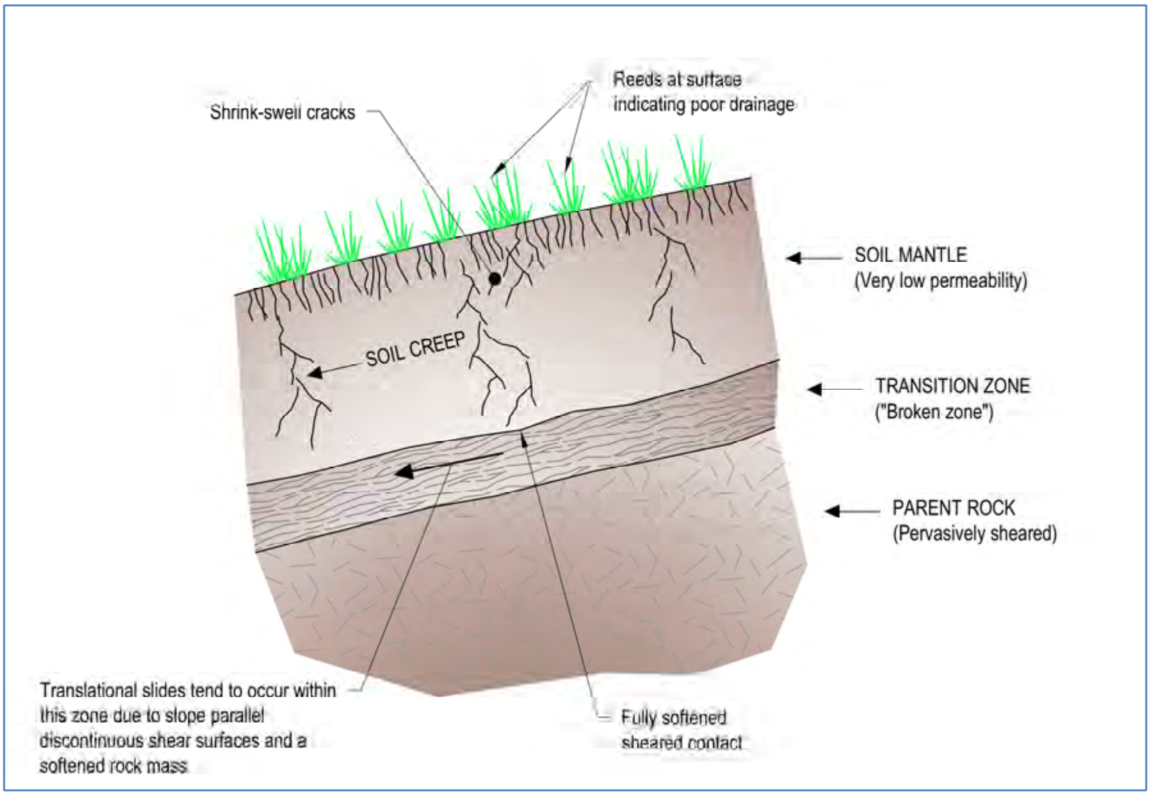


Figure 7: Typical Northland Allochthon ground profile

Table 2 Classification and characteristics of Northland Allochthon (based on Winkler, 2003 and East and George, 2001)

Zones (after Winkler, 2003)	Grade (after East and George, 2001)	General characteristics
Soil mantle	Completely degraded Northland Allochthon soil (V-VI)	Silty clay Very soft and wet in winter. Firm to stiff in summer sheared contact at base which is fully softened Low permeability resulting in ponding on the surface and reeds. High shrink swell
Transition zone ('broken zone')	Highly degraded Northland Allochthon rock/soil (IV)	Firm to stiff silty clays and clayey silts with gravel sized fragments derived from the underlying parent rock. Retains sheared and chaotic fabric of parent rock slope parallel discontinuous shear surfaces softened rock mass Higher permeability than the Upper Zone and the under lying parent rock.
Parent Rock	Moderately degraded Northland Allochthon rock (III)	Very fractured slickensided and polished very weak grey black and chocolate brown claystone/siltstone/muddy limestone in a clay/silt matrix (East and George, 2001). 'dry', broken, pervasively sheared rock mass. May have continuous shear zones.
	Northland Allochthon rock (II)	Very fractured slickensided and polished weak grey claystone/siltstone/muddy limestone with some clay matrix. 'dry', broken, pervasively sheared rock mass. May have continuous shear zones.

Slope failures on natural shallow angles are characteristic of Northland Allochthon terrain often resulting in flatter topography with rolling hills and subtle landslide features. Previous experience (Burt, 2003) indicates that creep failure occurs on shear planes in the transition zone between softened soil and the sheared rock mass.

The total thickness of the Northland Allochthon in the Schedewys valley was not proven but extended to at least 20mBGL in borehole BH109. The Schedewys valley Northland Allochthon is locally fault controlled with distinctive lineaments identified to the northern and southern extents of the Allochthon formation exposure.

Near the edge of Moirs Hill and Wreaks Road (a forestry road) a localised 'capping' layer of Northland Allochthon was returned as shattered mudstone in borehole BH210. Here the Northland Allochthon was proved to 14.5mBGL, directly overlying unweathered Pakiri Formation. A sheared contact between the two formations was inclined at 28° to the northwest.

The morphology suggests the Northland Allochthon 'capping' in this area may extend to the indicative alignment between approximate chainages Ch 57500 and Ch 57150, although this has not been proved by intrusive investigations to date.

5.3.2 Northland Allochthon properties

The engineering properties for the Northland Allochthon are related to the original rock lithology and degree of degradation (softening) of the material, and are shown in Table 3 below. These are based on the interpretation that the material belongs to the predominantly non-calcareous lithology of the Mangakahia Complex, and publications by Burt (2002) and Winkler (2003).

Table 3 Properties of Northland Allochthon

Zone	Unit Weight (γ,kN/m3)	Undrained shear strength	Effective strength		Residual effective strength	
		Su (kPa)	c' (kPa)	Ø' (deg)	cr' (kPa)	Ør' (deg)
Soil Mantle	18	30 to 70	-	-	0	10 to 13
Transition Zone	18	100 to 140	-	-	0	10 to 13
Parent Rock	18	NA	5	28	0	10 to 13

Note: residual values of effective strength parameters for the soil mantle and transition zone materials have been used in the stability calculations, reflecting the pre-sheared nature of these materials.

5.4 Alluvium

Alluvium varies widely in texture (grain size) and spatially (both horizontally and vertically). Alluvium has lower load bearing characteristics than the Pakiri Formation materials and may contain highly compressible layers of peat or organic rich clay and silt. Loose saturated sands and silt materials in alluvium could potentially be susceptible to liquefaction under certain seismic conditions, and an assessment of this hazard has been made in Section 5.7 below.

Alluvium is locally encountered throughout the indicative alignment in valleys but is most consistently present at the northern end of the indicative alignment in the Perry Road and Carran Road Sectors (from Perry Road through to the north of Woodcocks Road at Warkworth). In these locations the boreholes and Cone Penetration Tests (CPTs) encountered a 2m thick layer of organic silts and clays underlain by clayey silt with occasional lenses of organic material. The depth of the alluvium varies but was proven to 16.5m in borehole BH228.

Of particular note, borehole BH227 encountered a peaty / highly organic silt lens from 1.5m to 2.5m that may be indicative of other more extensive peat deposits within this formation.

Peak shear vane readings varied between 10 to 96 kPa and Standard Penetration Tests (SPTs) from 0 to 12. The alluvium tends to be highly sensitive with a high moisture content that makes it difficult to handle in bulk earthworks operations.

The engineering properties adopted in this appraisal for alluvium in the Perry Road and Carran Road sectors are shown in Table 4 below.

Table 4 Alluvium ground model and strength parameters adopted for Perry Road and Carran Road Sectors.

Depth profile (mBGL)	Geological formation	Undrained strength	Effective strength		Unit Weight
		S_u (kPa)	c' (kPa)	Ø' (deg)	(γ,kN/m^3)
0.0 to 2.0	Organic silts/clays	10 - 25	0	22 to 25	16.0
2.0 to 5.0	Very soft to soft silts/clays	10 - 25	0	22 to 25	16.0
5.0 to 12.0	Firm silts/clays	25 - 50	0	22 to 25	16.0
12.0 to 16.5	Firm to stiff silts/clays	50 - 100	0	22 to 25	16.0

5.5 Groundwater conditions

The hydrogeological regimes and characteristics of the main geological units are fundamentally different. These are discussed in detail in the Hydrogeology Assessment Report, but are summarised in the following sections.

Standpipe piezometers were installed in the majority of the boreholes in the Stage 2 geotechnical investigation to characterise the groundwater conditions. A number of boreholes in the locations of the deep cuts had ‘nested’ piezometers installed: two piezometers installed and sealed at different elevations within the borehole to monitor the possibility of percolating groundwater regimes.

The locations of the piezometers are represented on the engineering geological long section (Drawings GT-151 to GT-161). Refer to the Hydrogeology Assessment Report for details on the groundwater levels and hydrogeological testing.

Groundwater levels are typically lower and close to the surface in the valleys and alluvium areas, while in the upland areas typically comprising Pakiri Formation materials, groundwater elevations are higher but the groundwater depth from the ground surface is greater.

5.5.1 Pakiri Formation

In general, the vast majority of these rocks are of very low primary permeability and hydraulic conductivity. The secondary permeability (resulting from the number and condition of the rock mass defects such as bedding partings and fractures) will vary locally.

The strongly bedded nature of the sandstones and siltstones results in contrasting permeability and vertical anisotropy in hydraulic conductivity, with horizontal hydraulic conductivity typically 40 to 250 times greater than the vertical hydraulic conductivity (Tūhono Consortium, 2011).

Groundwater levels in the deeper Waitemata Group are deeper and typically range between 4 and 40mBGL. In contrast to the alluvium, groundwater levels in the deeper Waitemata aquifer have shown very little variation over time and in many cases (e.g. BH207, BH218, BH219 and BH223) have continued to recover (decline) following drilling.

In the more strongly alternating sandstone and siltstone deposits of the Waitemata Group rocks, perched groundwater tables are sometimes encountered above a low permeability siltstone bed above the regional water table. A cascading series of perched water tables may be present where percolating groundwater is regularly caught and held up by lower permeability layers, eventually slowly discharging through the rock mass and fractures to underlying layers (refer to Figure 9). The recognition of such a percolating groundwater model has important implications for slope stability, as discussed in Section 7.4.

An example of cascading and perched water tables is potentially shown by the nested piezometers installed in borehole BH217. The groundwater levels in BH217 tend to indicate multiple perched water tables, however the gravel packs may be acting as sumps and therefore not being a true reflection of groundwater pressures at each point in the profile. Further examination is discussed in the Hydrogeology Assessment Report.

A fracture zone encountered between 30.0 and 31.5m depth in BH215 was one of the few fracture zones intercepted in any of the drill core beneath the water table. Two packer tests were consequently carried out in borehole BH215, one over this fracture zone and one between 33 and 36m depth to investigate the permeability of non-fractured Pakiri Formation. A description of a packer test and the detailed results are provided in the Hydrogeology Assessment Report.

The packer test results indicated slightly elevated permeability in the fractured rock compared to the unfractured part (only approximately half an order of magnitude difference in permeability), suggesting the fracture is not hydrogeologically significantly different to the bulk rock mass. However, the presence of other fractured zones which may provide relatively greater groundwater inflows or pressures during excavation cannot be ruled out and will need to be identified during detailed investigations and by construction supervision.

5.5.2 Northland Allochthon

Northland Allochthon rocks can display highly variable and complex hydrogeological conditions relative to various response zone depths. They typically comprise very low permeability rocks with hydraulic conductivities (the ability of the rock to transmit water) generally less than 10^{-7} m/s.

The soil mantle and soil/rock transition zone often act as a confined aquifer with low hydraulic conductivities but with significant elevated pore water pressures.

5.5.3 Alluvium

While hydraulic conductivity of this material is typically low ranging from 10^{-8} to 10^{-7} m/s, higher hydraulic conductivities may be found locally where cleaner sands and gravels are encountered.

Measured groundwater levels in the alluvial deposits range from 0.2 to 0.9mBGL. The groundwater levels showed increased levels (less than 1m) in response to rainfall events.

5.6 Seismicity and fault hazards

The Auckland Region is one of the least seismically active regions of New Zealand. Auckland is over 200km from the seismically active boundary between the Australian plate and the subducting Pacific plate. The closest active faults are the Wairoa North Fault located in the Hunua Ranges south-east of Auckland approximately 75km to the south of the Project and the Kerepehi Fault within the Firth of Thames (Edbrooke, 2001). Another considered potentially active is the Drury Fault on the edge of the Hunua Ranges (Williams, et al., 2006).

Published empirical relationships and recent unpublished studies have suggested single earthquake events on the Wairoa North Fault may give rise to events with an earthquake magnitude in the order of 6.8 (Stirling et al, in press).The Kerepehi Fault has been estimated to be capable of generating earthquakes of about Magnitude 7 with a recurrence interval of 3600 years (Edbrooke, et al., 2013).

There has been negligible seismic activity over the last 100 years in the Auckland region, with the exception of some low-level seismicity:

- A Magnitude 4.5 earthquake which was centred 30km east of Orewa in the Hauraki Gulf on 21 February 2007. The earthquake was felt from Warkworth in the north through to Waihi at the base of Coromandel Peninsula (GNS Science (GNS) News Release, 22 February 2007). Two smaller earthquakes occurred within hours of the main earthquake and were of magnitude 3.7 and 3.8;
- Two earthquakes on 17 March 2013 measuring Magnitude 3.1 and 3.9, situated at depths of 4km and 6 km respectively and centred 15km northeast of Auckland at Motutapu Island, next to Rangitoto Island (GNS Geonet). The earthquakes were both felt as far north as Warkworth. The M3.9 event was felt as far south as Waihi at the base of Coromandel Peninsula and the M3.1 event was felt as far south as Papakura, South Auckland (GNS News Release, 17 March 2013).

The ground shaking hazard within the study area for an earthquake is generally low due to the general absence of significant thicknesses of unconsolidated sediments and the consequential earthquake effects. However, the estuary around the Pūhoi River, the estuary around Okahu Creek and the flat area of Kaipara Flats to the west of Warkworth have a relatively higher ground shaking hazard due to the presence of deeper and softer estuarine and alluvial deposits.

5.7 Liquefaction

Liquefaction hazards primarily exist in areas of saturated, unconsolidated, finer-grained soils although coarse-grained soils may be susceptible to liquefaction under certain seismic conditions. Liquefaction can lead to significant subsidence and / or lateral spreading of embankments and can severely impact structural foundations.

The primary areas where soils may be considered to be potentially susceptible to liquefaction are:

- Alluvial and estuarine sediments in the Pūhoi River valley (the areas of alluvium around Okahu Creek and Pūhoi River).
- Extensive alluvial deposits in the Woodcocks Road area.
- Soft alluvial deposits at the northern tie-in to SH1.

The Project Team undertook a preliminary liquefaction assessment for embankments and structures sited on the alluvium in the Woodcocks Road and Northern SH1 connection from the available borehole and CPT data. The preliminary assessment indicates that liquefaction is unlikely to be a hazard and liquefaction induced settlement is anticipated to be negligible based on the anticipated presence of predominantly organic silt/clay layers.

Notwithstanding this preliminary assessment, due to the variability of the ground conditions within the indicative alignment, local liquefaction prone areas might yet be encountered. Further site specific investigation and liquefaction assessments of critical design elements such as the viaduct structures will be necessary to advance their detailed design in accordance with the design requirements outlined by the NZTA Bridge Manual guidelines and NZS:1170.5 standard.

5.8 Landslides

5.8.1 Regional landslide distribution and landslide hazard

The geology and geomorphology are the principal conditioning factors that lead to the land instability between Pūhoi and Warkworth. The majority of the natural slopes encountered by the Project are typically moderate to very steep (25-40°) and underlain by weathered materials of the Pakiri Formation.

There is widespread evidence of shallow soil creep and shallow landslides in these materials in the vicinity of the indicative alignment and numerous examples of pre-existing historical and current instability on the present road network.

5.8.2 Soil creep

Soil creep (very slow, seasonal, shallow slope movement) is widespread. Creep is readily observable across many steeper slopes of the Pakiri Formation and moderate slopes of the Northland Allochthon in the form of 'terracettes' or small regular benches on the hillsides. In the majority of cases creep is not a significant concern for the Project but may in some areas require additional minor engineering work to stabilise the slopes. These issues can be addressed at the detailed design stage. Relatively simple solutions such as installing drainage or shaping the upper parts of the cut slopes to flatter batter angles have been successfully applied elsewhere in similar conditions.

5.8.3 Debris flows

Debris flows are a fast flowing mixture of water with a medium or high proportion of solids, which moves down watercourses. Debris flows are triggered by heavy rainfall and can often occur in conjunction with landslides within the catchment. Debris flows are potentially destructive and can encompass a wide range of objects, such as fallen trees, stumps, boulders, gravels and soils, plus water.

In steep terrain, rainfall-induced channelised debris flows and gully erosion are a hazard for potential road alignments crossing steeply incised gullies where loose soil or debris is present on the gully floors or flanks. Removal of forested areas either for the construction of the Project or as a result of other surrounding land-use will increase the potential for debris erosion and sediment transport to occur.

These hazards have been considered and addressed in the Operational Water Assessment Report, including the development of a Debris Management Framework. The framework will be updated at the detailed design stage.

For catchments with a high risk of debris flow, mitigation measures include the construction of debris control structures such as mounds and steel trash racks upstream of the culvert (e.g. Drawing SW-305). Further mitigation is provided by sizing the culverts with additional capacity to reduce the potential risk of blockage due to debris and by installing secondary relief inlets with debris screens (refer to Drawing SW-306) to allow water flow to continue.

5.8.4 Landslides – Pakiri Formation

The majority of the landslides to be encountered by the indicative alignment are shallow translational or shallow earthflows less than 5m deep. They are common in the steeper slopes of the weathered Pakiri Formation.

Larger landslides in the Pakiri Formation are often controlled by the underlying geological structure such as bedding and/or persistent fractures. They tend to have occurred where the bedding in the sandstones and siltstones is inclined out of the slopes or where there is a sharp interface /contact between the weathered overburden materials (soil) and underlying rock.

Several large, shallow translational landslides remain in the heads of some of the larger gullies crossed by the indicative alignment at lower elevations but in the majority of cases the failed material has already predominantly been evacuated by erosion processes or has been remobilised as earth debris flows. On the valley sides a number of translational slide masses contain failed blocks which remain relatively intact though somewhat deformed.

There are some large deep-seated landslides in the Pakiri Formation that could not be avoided through route selection (for example, in the Billing Road area). The deep seated landslides are predominantly considered inactive under the prevailing conditions. The deep seated failures appear as large translational or block slides, which are most likely controlled along planes of structural weakness such as bedding-parallel clay seams or fault zones. The significant and deep-seated landslides are discussed further in Section 9.

5.8.5 Landslides – Northland Allochthon

Slope instability is common in Northland Allochthon materials in the Auckland and Northland Regions often observed on slopes as low as 8-10°. Typically, shallow sliding occurs along shear surfaces in the transition zone between the soil mantle and the underlying sheared rock masses. Shallow landslides are mapped in the Northland Allochthon materials crossed by the indicative alignment. In conjunction with consideration of other environmental constraints and hazards, the indicative alignment has minimised where possible the exposure to the large or deeper-seated block landslides in this material.

6. Geotechnical design philosophy

6.1 Summary of geotechnical design philosophy

The geotechnical design philosophy is based on identifying, avoiding where possible, or minimising key geotechnical risks and environmental impacts whilst making use of geotechnical opportunities to provide a safe, secure and constructible indicative alignment and design that meets the RoNS objectives.

The existing State highway network between Pūhoi and Wellsford is susceptible to landslides and flooding in heavy rainfall events. The Pūhoi to Warkworth Project will enable a substantial improvement over the safety and security of the existing SH1 in this section of the route.

The indicative road alignment and proposed designation has taken into account, where possible and practicable at this stage of the design:

- Avoiding or minimising exposure to major landslides and rock falls;
- Minimising exposure to potentially liquefiable and very soft soils;
- Avoiding large retaining walls and structures;
- Avoiding structures on steep or unstable slopes;
- Maintaining flexibility and scope for future design innovations and improvements; and
- Using reinforced soil (MSE embankments) to steepen embankment slopes and reduce the construction footprint.

The engineering geological mapping and preliminary geotechnical investigations identified the following key components for consideration in the geotechnical assessment:

- Cut slope stability and rock fall hazards;
- Fill embankment stability and ground improvements;
- Landslides;
- Earthworks properties;
- Spoil disposal and stability; and
- Structural foundations.

Based on the engineering geological model developed from the investigations to date and from the lessons learnt from the design and construction of similar major highway schemes in similar geological conditions and terrain, we have developed feasible geotechnical designs for concept design. These have been developed to inform a proposed designation width and assessment of effects for the Notices of Requirement and resource consent applications.

The detailed geotechnical designs for the Project will be carried out in accordance with standard geotechnical design guidelines and accepted New Zealand design criteria and standards defined in documents such as:

- NZ Transport Agency Bridge Manual (SP/M/022 3rd Edition May 2013)
- New Zealand Standard NZS 1170.5:2004 Seismic Loadings Code (Standards NZ, 2004)

- NZ Building Code (Parliamentary Counsel Office, 1992)
- NZTA Road Research Unit Bulletin No.84 Vol 2: Seismic Design of Bridge Abutments and Retaining Walls (Wood and Elms, 1990)
- National Center for Earthquake Engineering Research Technical Report 97-022, Method and Recent Developments in Research Using both SPT & CPT (NCEER, 1997)
- Australian Standard AS-4678:2002 Earth Retaining Structures (Standards Australia, 2002)
- Australian Standard AS-2159:2009 Piling Design and Installation (Standards Australia, 2009)

As such, the Project's geotechnical structures and earthworks will be designed with appropriate margins of safety for stability and with acceptable ground-related deformations.

6.2 Seismic criteria

Seismic design loads for detailed design will be based on criteria outlined in the NZ Transport Agency Bridge Manual (NZTA, 2013) and NZS 1170 (Standards NZ, 2004).

For this appraisal the Project Team has adopted the seismic criteria as summarised in Table 5.

Table 5 Seismic Acceleration Criteria*

Design Element	Annual probability of exceedance for the ultimate limit state	Horizontal Peak Ground Acceleration coefficient
Bridges and retaining structures associated with bridges. Retaining structures ≥5m height and ≥100m^2. Retaining structures protecting against loss or significant loss of functionality to adjacent property.	1/2500	0.28
Embankments >6m height Earth slopes providing protection against loss or significant loss of functionality to adjacent property. Retaining structures <5m height or <100m^2.	1/1000	0.20
Embankments ≤6m height. All cuttings in soil. Minor retaining structures on other than primary route.	1/500	0.19

* For Class C shallow soil sites (NZS 1170.5)

Liquefaction assessments have also considered the horizontal peak ground accelerations corresponding to a magnitude 7.5 earthquake.

The Bridge Manual requires that a site specific seismic hazard study be undertaken for soil structures and earthworks of values more than $7 million (December 2012 values) or potentially less for areas of potentially liquefiable materials.

6.3 Slope stability design criteria

The criteria adopted for our stability assessment of cut and embankment slopes are outlined in Table 6. For slope stability, the factor of safety below refers to the ratio of the average resisting forces along a slip surface to the average applied force. In simple terms, a factor of safety value of 1 represents 'critical' equilibrium and implies that a slope is on the verge of failing.

Table 6 Factors of safety for slope stability preliminary assessments

Case	Factor of Safety
Static, short term (construction)	≥1.2
Static, long term	≥1.5
Seismic (pseudo static) Horizontal ground accelerations according to the seismic design criteria adopted for the preliminary assessment.	≥1.0 or permanent displacements ≤150mm (excluding slopes associated with structures)

Note that, apart from walls or slopes supporting bridge abutments or piers, the Bridge Manual allows for factors of safety <1 under design earthquake loads provided that permanent displacements are within tolerable limits.

6.4 Design features of specific interest

We have analysed and assessed a selection of design features in further detail to demonstrate that the typical design configurations and concepts are feasible and appropriate. Our assessments have used data specific to this indicative alignment plus data and geotechnical design solutions applied to other major schemes in similar terrain, such as the NGTR design.

The features selected for specific assessment have included:

- Locations of cuts and embankments where slope heights, cutting depths and topography reflect the 'worst-case' scenarios;
- Examples of typical design elements; and
- The features of specific interest have been identified and discussed in each of the following sections.

7. Cut slopes

7.1 Cut slope design philosophy

The stability of cut slope batters will be a significant design component.

Due to the steep terrain with numerous ridges and valleys the indicative alignment will involve numerous cuts into the hillsides, with resulting cut slopes ranging in height up to 70m and with many exceeding 10m. The major cut slopes in excess of 35m height are presented in Table 7.

Cut slope gradients adopted in the design range from 1V:1.2H (40°) to 1V:5H (11°).

At this concept design stage most of significant cuttings on the indicative alignment are expected to be within Pakiri Formation terrain with the exception of two relatively small cuttings in Northland Allochthon materials.

Table 7: Major cut slopes along the indicative alignment.

Sector	Chainage	Cut slope length along the alignment (m)	Maximum cut depth below ground level (m)	Maximum cut slope vertical height (m)
Hungry Creek	61940-62540	600	28	50
Hungry Creek	60280-60740	460	24	47
Schedewys Hill	57900-58400	500	34	45
Schedewys Hill	56800-57140	340	36	40
Moirs Hill Road	56420-56760	340	40	50
Moirs Hill Road	55720-56110	390	50	60
Moirs Hill Road	55060-55330	270	40	50
Moirs Hill Road	53820-54540	720	46	50
Perry Road	52430-52920	490	38	50
Perry Road	50540-50820	280	30	35

Notes

1. Cut depth is maximum depth of excavation below the current ground level surface. The maximum cut depth below ground level can occur at an offset from the centre line of the road.
2. Cut slope vertical height is the vertical height of a cut slope, taken as the difference in elevation between the base of the cut and the crest. In sloping topography, the cut slope height can be much greater (or less) than the cut depth, particularly where sideling cuts are made.

The concept design for cut slopes has been developed to provide for stable cuts using a variety of cut slope batter angles according to the anticipated geotechnical conditions. Localised or site-specific treatment and additional stabilisation measures will be incorporated during detailed design and construction phases where the revealed conditions differ.

The cut slopes design criteria will consider:

- Normal static conditions
- Earthquake (seismic) activity
- Elevated groundwater conditions
- Temporary construction conditions

For this appraisal the cut slope design philosophy and profile configuration has been developed based on the following:

- Precedence from the design, construction and performance of similar roading schemes and major earthworks in similar geological conditions (for example NGTR and ALPURT A1).
- Performance of existing cut slopes in the local terrain (for example, existing SH1 cuts at Pohoehoe Viaduct, NGTR, and cuts at Waiwera Hill on the Hibiscus Coast Highway).
- Anticipated geological profile and preliminary information from Stage 1 and Stage 2 intrusive geotechnical investigations (Refer Section 7.2).
- Slope stability analyses to test the sensitivity of the adopted generic slope profiles to local variations in groundwater level and weathering depths.
- A review of rock fall hazards.

7.2 Generic ground model for cuts in Pakiri Formation terrain

To establish an engineering geological model the Project Team has considered the variation in weathering depths of the Pakiri Formation.

Figure 8 shows the variation in the weathering encountered in the Pakiri Formation terrain along the indicative alignment by the Stage 1 and Stage 2 geotechnical investigations. The boreholes shown on Figure 8 are predominantly located on ridges or the sides of valleys and are therefore representative of the ground to be encountered in the road cuttings.

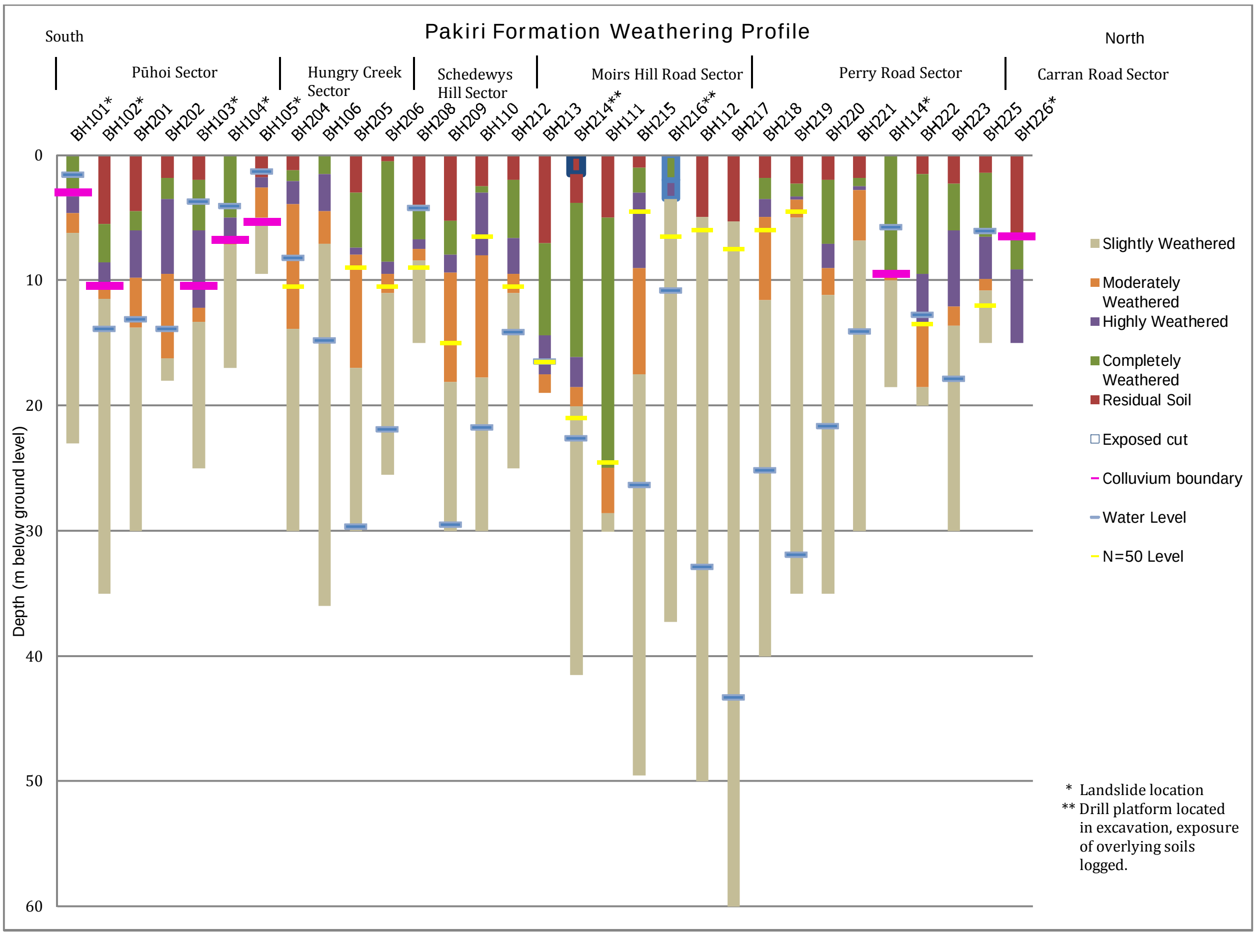


Figure 8: Depth of weathering in boreholes in Pakiri Formation terrain

Based on the available data a preliminary generic weathering profile for the cut slope profiles in the Pakiri Formation throughout the route length (refer to Table 8 below) has been developed. The generic weathering profile is considered a conservative estimate for initial cut slope design in order to provide an adequate designation width for the indicative alignment and a provisional estimate of earthworks quantities.

Table 8: Generic weathering profile for Pakiri Formation cuts.

Weathering Profile	Generic Ground Model assumed for consent design and assessment of effects	Median from Stage 1 and 2 preliminary ground investigations (n=31)	Average from Stage 1 and 2 preliminary ground investigations (n=31)	Standard deviation
Colluvium / residual soil / completely weathered Pakiri Formation	10m depth	6m depth	6.6m depth	4.7
Highly weathered (HW) and moderately weathered (MW) Pakiri Formation	10m thickness, from 10m to 20m depth	4.35m thickness, to 11.5m depth	5.6m thickness, to 12.2m depth	4.1 (thickness of HW/MW)
Slightly weathered (SW) and unweathered, competent Pakiri Formation	from 20m depth	from 11.5m depth	from 12.2m depth	5.6 (depth to MW/SW boundary)

Preliminary geological sections for a sample of major cut slopes where some investigation has taken place are presented in Drawings GT-231 to GT-234.

Detailed investigation will need to be carried out to produce site-specific ground models over the whole route prior to construction as the generic ground model does not take into account local effects that may have influenced the weathering and strength profile, such as existing defects (for example, fracture zones) or local bedding dip direction.

Where the recent geotechnical investigations consistently encountered a significantly shallower weathering profile than in the generic model, the cut slopes investigated were adjusted to a more ‘site-specific’ weathering profile, albeit maintaining an element of conservatism due to the limited data to date. Significantly shallower weathering occurs for example at Ch 60250-60730.

A noteable exception to the generic ground model is in the area of Moirs Hill Road where preliminary investigations have recorded a deeper weathering profile (boreholes BH111, BH213, BH214 in Figure 8 above). This discrepancy was compensated by locally adjusting the cut profile to reflect the deeper weathering (e.g. refer to Drawing GT-233).

The generic weathering profile in Table 8 is not representative of the conditions in the valley floors and gullies and is therefore not applicable for preliminary assessment of embankments. The mapping observations suggest the depth of weathering of the Pakiri Formation rock is less in the very base of the narrow gullies but can be overlain by alluvial and / or colluvial deposits. Slightly weathered rock is exposed in many of the steeply incised gullies as illustrated on the geological long section.

7.3 Cut slope angles

The cut slope angles adopted for the generic ground model are summarised in Table 9 below.

Table 9 Cut Slopes Adopted for Generic Ground Model

Geology	Depth Profile for Cut Slopes	Cut Slope Angle (Vertical (V) : Horizontal (H))	Notes
Pakiri Formation (refer to Drawing R-211)	0 – 10m	1V : 3H (18°)	Assumes maximum depth of colluvium / residual soil/ completely weathered material is 10mBGL.
	10 – 20m	1V : 2H (26°)	Assumes maximum depth of highly and moderately weathered Pakiri Formation is 20mBGL.
	>20m	1V : 1.2H (40°)	Assumes slightly weathered to unweathered, competent Pakiri Formation rock from 20mBGL. This material will often require breaking and blasting.
			Additional Notes: An allowance is included for a rock debris trap between the toe of slope and the road. Bedding shears and defects can impact on stability at any depth. Site specific assessment and detailed design will be carried out. Particular attention required at interface between highly weathered and moderately unweathered zones where this unit is pre-disposed to instability. Northern Allochthon material can occur in isolated small pockets within Pakiri Formation, even at the higher elevations (e.g. preliminary interpretation of BH210).
Northland Allochthon – Mangakahia Complex or undifferentiated.	All depths	1V : 5H (11°)	Assume that groundwater will be intercepted. Include horizontal bored drains at 5m intervals.

Note: 1V:3H means a slope ratio of 1 vertical to 3 horizontal.

The determination of the proposed cut slope angles has included the following considerations:

- A workshop held between key geotechnical and environmental specialists in the Project team that identified the key design and environmental aspects of possible slope configurations drawn from experience;
- Proposed cut slope angles to match the surrounding landscape. For example, natural slopes in the Pakiri Formation are in the order of 25-40°, consequently the proposed slopes match the surrounding landscape compared to steeper slopes;
- Cut slope angles increase with depth in the Pakiri Formation to match the natural weathering profile and ground model. This design results in a slope configuration that also more closely resembles the natural profiles of the surrounding landscape with steeper side slopes in the deeply incised gullies;
- Overall cut slopes are similar to stable cut slope angles adopted for existing sections of the ALPURT and NGTR motorways in similar formations;
- Waitemata Group soils in other major earthworks in the Auckland Region are typically excavated to long term stable slopes of between 1V:2H and 1V:3H. Locally, the degree of weathering, groundwater conditions and cut slope height impact on the slope gradient adopted;
- Moderate soil cut slopes of 1V:5H to 1V:2H result in more practicable and successful revegetation. It is recognised that erosion protection of cut slopes has to be provided as soon as practicable after excavation to minimise potential rilling on the slope face;
- The proposed rock cut slopes are similar to the 41° slopes adopted for the NGTR motorway immediately to the south of the Project;
- Cut slopes steeper than 40° have a greater risk of 'bouncing' rock falls (Wyllie and Mah, 2004). The rock fall hazard is discussed further below;
- The conflicting desire to minimise the overall footprint of the road yet ensuring sufficient provision is made in the proposed designation to take account of the variable ground conditions that may be identified during later stages of investigation and construction;
- The proposed designation is adequate for alternative design configurations (for example, the inclusion of intermediate slope benches);
- It is generally accepted that cut slope gradients in Northland Allochthon materials generally need to be low and as close as possible to the natural slope profile otherwise failures in the cut can be expected; and
- Experience in road cuttings along the SH1 ALPURT alignment and trial cuts monitored in typical Northland Allochthon materials (excluding Mahurangi Limestone) show gradients in the order of 1V:4H to 1V:5H are generally considered to be optimal for long term stability (Opus, 1997). It has been recognised that there are some recent "nuisance factor" landslides in Northland Allochthon slopes at this low gradient on ALPURT sections of the Northern Motorway over the last few years.

7.4 Cut slope stability

7.4.1 Structural control on slope stability

The stability of cut slopes is highly dependent on the orientation of the existing geological structure (bedding planes, shear planes, joints, faults). Determination of the local geological structure is critical for the detailed design of cut slopes in both the weathered and unweathered rock masses.

The main mechanisms of structural control in the road cuttings comprise (based on Moon and Healy, 1994):-

- *Planar block failure* along bedding plane partings where bedding is inclined out of the cut faces at a sufficient angle for shear failure. Planar failure types are often evident in the Pakiri Formation at the soil/rock interface particularly where a sharp weathering transition is present. Perched water at inclined interfaces such as these increases the instability and the overlying soils can slide over this interface unless supported or removed.
- Discontinuity surfaces (joints, fractures, shear zones, fault planes or fault zones) oriented sub-parallel to the cut faces, that have a significant dip angle out of the cut face and daylight in the excavation, also have the potential for *planar failure* dependent on the shear strength of the discontinuity surfaces.
- *Wedge-type failures* occur where fractures in the rock of different orientations intersect, and this intersection daylights on the cut face at a steep angle, causing a wedge-shaped body of rock to slide out of the face. In the Waitemata Group rocks this often only occurs where faults intersect other major fractures.
- *Rock fall failures* may occur where the relatively weak siltstone underneath a regularly jointed sandstone bed is eroded by fretting due to cycles of wetting and drying and the sandstone block collapses.
- *Toppling failures* occur where a steep column or block of rock rotates about a fixed base. This situation is highly unlikely to occur on the Project due to the low cut slope angles that have been proposed.

Experience from the construction of the NGTR shows that cut slopes need to be carefully logged and monitored during construction to recognise significant geological structures (including thin low strength defects) and determine their condition and implication on slope stability (pers. comm. B. Hegan T&T, 2013). In some cuts on NGTR significant treatment was required during construction based on the geological structures revealed during excavation.

7.4.2 Groundwater control on slope stability

Groundwater has a significant influence on the stability of cut slopes. The details of the regional groundwater conditions along the indicative alignment are discussed in the Hydrogeology Assessment Report.

Groundwater in the steeply sloping and deeply incised elevated terrain of Pakiri Formation along the majority of the indicative alignment is strongly influenced by the valleys with the groundwater surface generally at significant depth beneath many of the proposed cuts as illustrated on the geological long sections. However, in localised areas where groundwater levels are significantly above the moderately weathered material this can lead to potential instability, particularly where a sharp soil/rock weathering interface dips out of the cut slope.

Perched groundwater and/or percolating groundwater may be present at higher elevations than the regional groundwater table in discrete localities, reflecting the inter-bedded nature of the sandstone / siltstone formation and typically lower permeability of the siltstones which act as an aquitard. However, at this stage of design, insufficient data is available to confirm the presence and accurately predict the elevation of percolating groundwater levels. Therefore, a hydrostatic groundwater profile has been adopted as a more conservative groundwater model for slope stability analyses.

The difference between a percolating and hydrostatic groundwater model is illustrated in Figure 9.

Furthermore relatively high piezometric levels in relation to the observed groundwater levels have been adopted in the stability analyses.

Where high water tables are encountered during construction, as evidenced by monitoring in piezometers or observations of groundwater seepages from slopes, these may be addressed by drilled horizontal drains or counterfort drains, located to maintain groundwater levels at levels that ensure the stability of the slopes. Mid-slope shear key treatments may also be applied in zones of weaker materials and/or localised high pore water pressures. The localised groundwater effects on slope stability will be reassessed as additional information is collated through the detailed design process, future groundwater monitoring and supervision during construction.

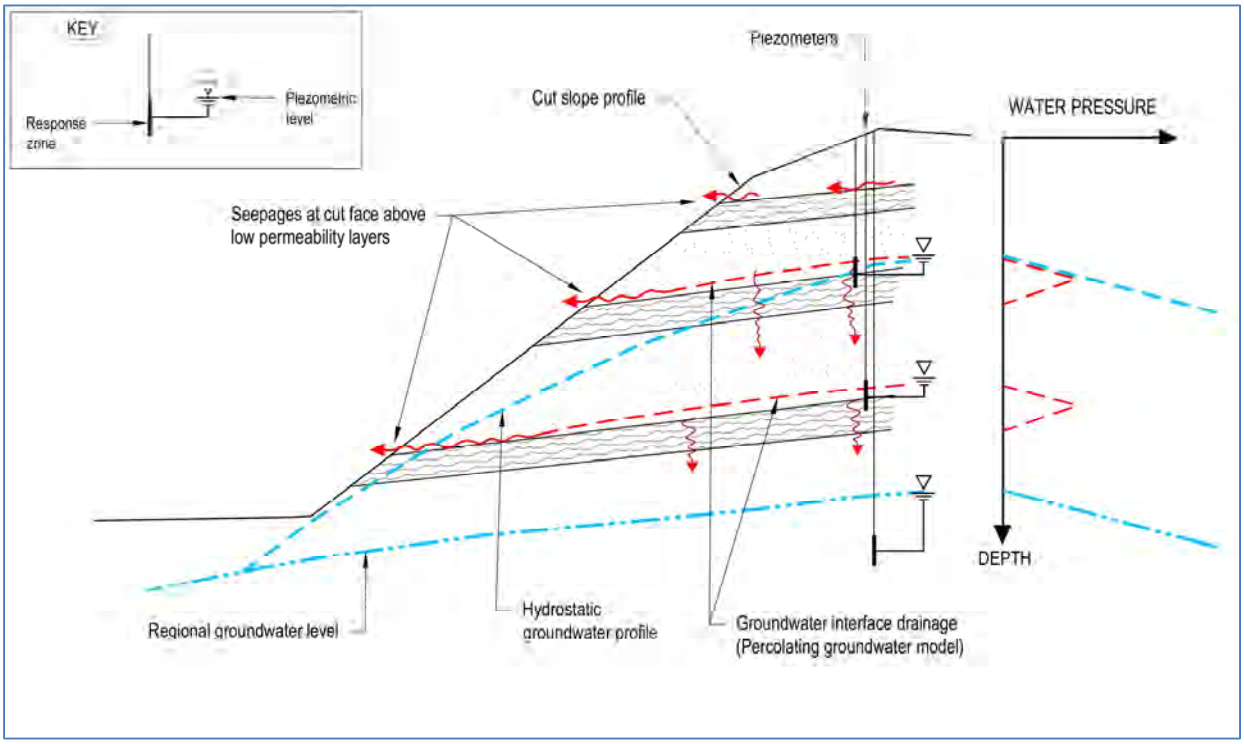


Figure 9: Percolating groundwater in layered Waitemata Group rocks in comparison to a hydrostatic groundwater profile.

7.4.3 Slope stability analyses

The Project Team have carried out geotechnical stability analyses on a selection of some of the higher cut slopes on the indicative alignment (e.g. Ch 51750, Ch 54100 and Ch 56200) to verify the stability of the proposed generic cut slope profiles.

Slope stability analyses were performed using the Geostudio 2007 Slope/W computer program. Circular and non-circular failure mechanisms using the Morgenstern-Price method were analysed in order to locate a global minimum factor of safety. The results of the analyses are summarised in Table 10.

Table 10: Slope Stability Summary

Chainage	Analysis Type	Required FoS	Design Factor of Safety
Cut, Ch.51750	Short Term	1.2	1.6 (satisfactory)
	Long Term	1.5	1.6 (satisfactory)
	Seismic	1.0	1.1 (satisfactory)
Cut, Ch.54100	Short Term	1.2	1.6 (satisfactory)
	Long Term	1.5	1.7 (satisfactory)
	Seismic	1.0	1.2 (satisfactory)
Cut, Ch.56200	Short Term	1.2	1.8 (satisfactory)
	Long Term	1.5	1.8 (satisfactory)
	Seismic	1.0	1.3 (satisfactory)

Slope stability analyses for the selected cuts satisfy the minimum design factors of safety under the conditions analysed. However, under a combination of unusually deep weathering (say where highly weathered material is assumed to extend from 10 to 20mBGL and with no moderately weathered material or increase in strength over this depth range) plus high groundwater levels, further stabilisation measures are required as discussed above in Section 7.4.2. Based on the information to date, these conditions are considered to be unlikely or only exist in localised situations.

7.5 Rock fall hazards

7.5.1 Rock fall behaviour

Rock fall in the Waitemata Group rocks typically occurs from more competent sandstone layers as the blocks of sandstone lose support by the frittering and removal of loose siltstone beneath them (Figure 10). Rock falls in Waitemata Group rocks (Pakiri Formation) are typically cubic to tabular shaped sandstone blocks of various strengths.

It is also possible in the Pakiri Formation that frittering and erosion of materials surrounding corestone remnants in the highly weathered rock mass could result in loosening and rock fall of more rounded rock fragments.

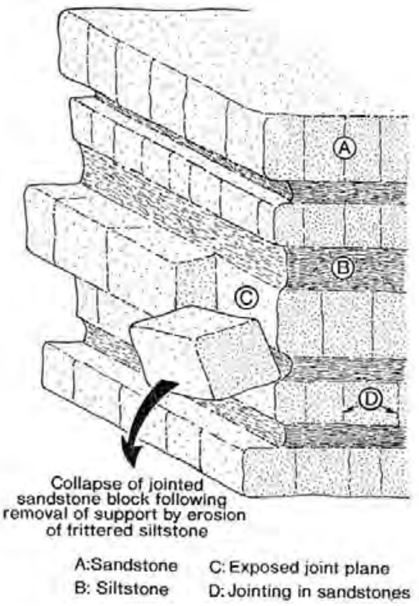


Figure 10: (a) Common rock fall mechanism in the Waitemata Group rocks (from Moon and Healy, 1994) (b) Example of small sandstone rock fall by frittering of underlying siltstone.

From field testing, Ritchie (1963) summarised the effect of slope angle on the rock fall behaviour as shown in Figure 11.

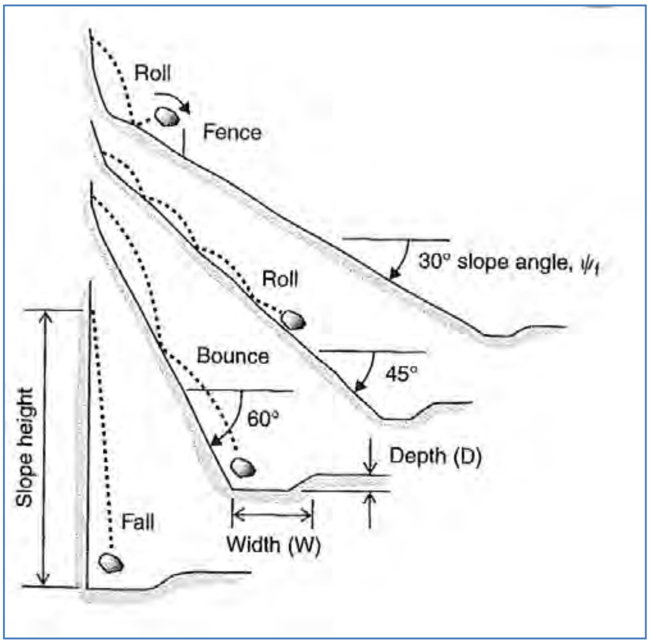


Figure 11: Rock fall behaviour (Wyllie and Mah, 2004)

Wyllie and Mah (2004) summarise rock fall behaviour as:

- *For slopes steeper than about 75°, the rocks tend to stay close to the slope face and land near the toe of the slope.*
  This case is evident in numerous rock fall cases associated with many steep and near vertical coastal Waitemata Group cliffs around the Auckland coastline. The materials encountered in the Project are generally not of sufficient strength to stand at these angles and at the same time meet the RoNS design criteria therefore this behaviour is not applicable.
- *For slopes between about 55° and 75°, falling rocks tend to bounce and spin, with the result that they can land a considerable distance from the base.*
  The Project cut slopes are designed at flatter slope angles to minimise the risk of this behaviour and avoid a widespread need for rock fall fences, barriers or wide catch ditches.
- *For slope angles between about 40° and 55°, rocks will tend to roll down the face and into the ditch.*
  The Project cut slopes have been designed to be at the lower end of this range such that the majority of dislodged rocks exhibit rolling or sliding behaviour down the slope face so as to minimise the risk of bouncing rocks.

7.5.2 Precedence of rock fall hazards from NGTR

The proposed deep cuts on the indicative alignment are similar to those designed in road cuts at Chin Hill at the northern end of NGTR and on the Hibiscus Coast Highway around Waiwera.

A previous rock fall field trial carried out during the construction of the large Chin Hill rock cut on the NGTR (NGA, 2008b) showed that on a 41° cut slope in Pakiri Formation materials, rocks released from a height of 30m tended to roll initially and then only bounce near the toe of the slope.

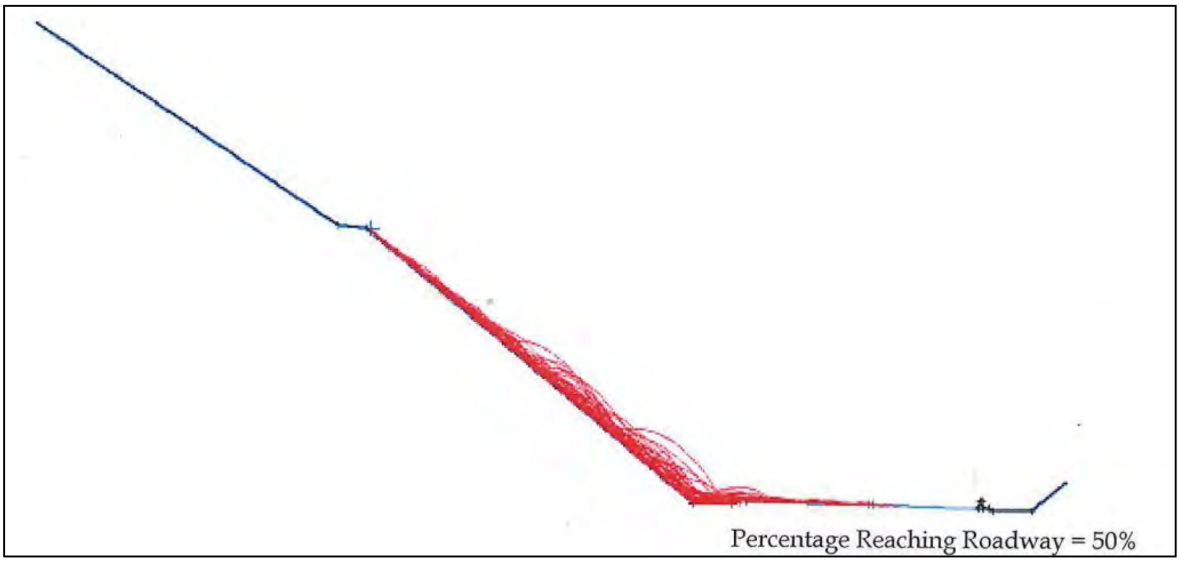


Figure 12: Results of RocFall hazard model for Chin Hill on NGTR with no protection measures in place (NGA, 2008b).

Based on the rock fall field trial and subsequent analysis using the RocFall software computer modelling (Figure 12), the NGA assessment concluded that in the event of a rock fall there is a high risk that rolling or bouncing rocks will land on the motorway if protection measures are not put in place (NGA, 2008).

The NGA also carried out a Rock Fall Hazard Rating System risk analysis and a quantitative probability estimate. This work indicated that the probability of a rock fall occurring and causing a motorist fatality would be on the limit of international acceptable risk criteria if no rock fall protection measures were put in place. Consequently, a 'cushioned ditch' and concrete barrier system was installed.

To date there have been only a few isolated incidents of rock falls from cuts in the Pakiri Formation rocks on the NGTR. As far as the Project Team is aware no rock falls have affected the carriageway, although an official record of rock fall incidents is not maintained (pers. comm. Peter Mitchell, Auckland Motorways Alliance, 2013).

In August 2012 a large fallen rock did not bounce onto the carriageway as it was cushioned by the swale and captured by a concrete roadside barrier even though the effective barrier height had been reduced by excessive build-up of slope eroded silt (Figure 13). Effective maintenance requires this silt to be removed on a regular basis.

The low incidence of rock falls demonstrates the effectiveness to date of the NGTR rock fall design. As the deep cuts on this Project will be formed at an almost identical slope angle to Chin Hill and within similar geological materials it may be assumed that a similar rock fall hazard exists. Consequently, rock fall mitigation measures are also recommended and have been incorporated into the concept design (refer to Section 7.5.3 below).

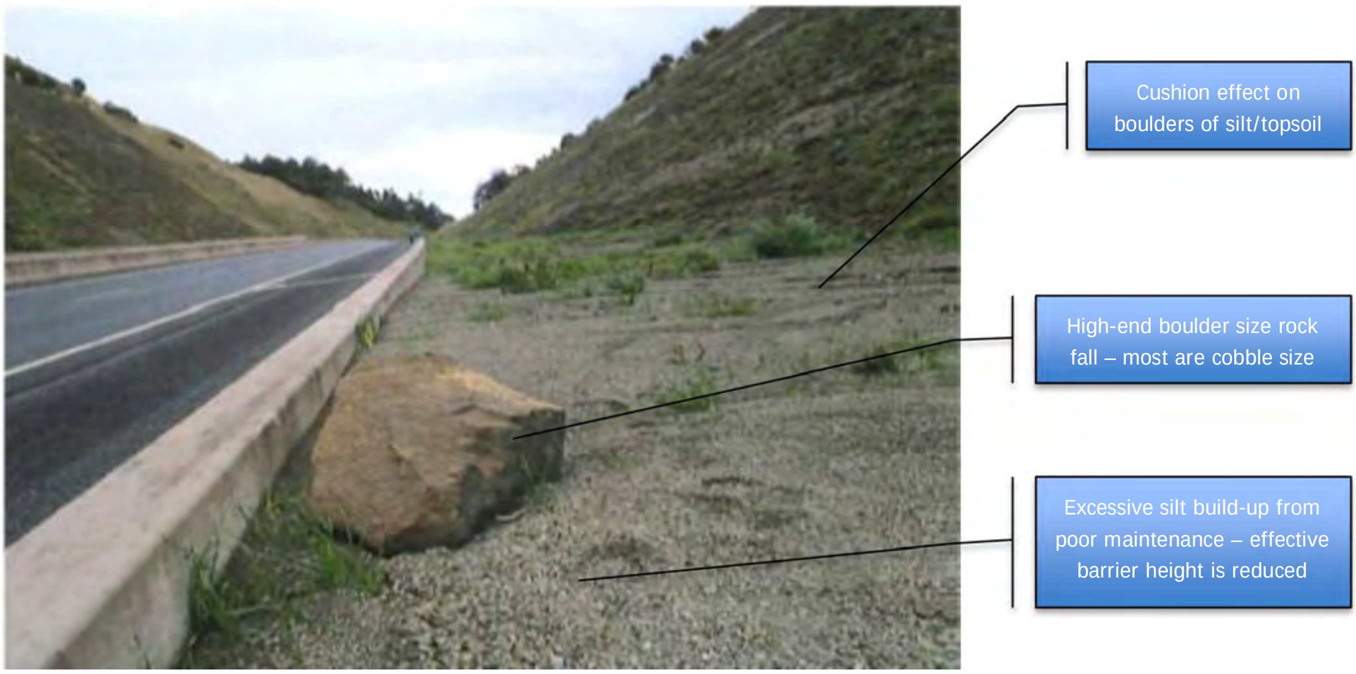


Figure 13: Example of rock fall contained by rock fall ditch and barrier protection design on NGTR.

7.5.3 Rock fall mitigation

Common methods of rock fall protection measures include cut benches, rock impact fences and barriers, rock bolting, and rock fall catch ditches.

Allowance for rock fall catch ditches has been included in the current design and are described below.

Ritchie (1963) developed a widely used empirical design chart for rock fall catch ditches based on field testing of rock falls. For concept design the Ritchie design chart has been used to identify the size and width of a rock fall catch ditch for various rock slope heights (Table 11). Typical details are shown on drawing R-213.

Table 11 Rock fall catch ditch dimensions for concept design, with wire rope safety barrier

Height of 40° rock slope (SW-UW* Pakiri Formation), H (m)	Catch ditch width, W (m)	Catch ditch depth, D (m)
0- 10	4.0	1.3
10-20	4.5	1.8
20-30	4.7	2.0
30-40	5.0	2.2

*SW-UW=Slightly to Unweathered

A variety of rock fall catch ditch and barrier options should be considered for detailed design according to the site specific geological conditions and cut slope profile. A rock fall trial may also be required to support the detailed design process.

7.6 Slope stabilisation measures

Due to the variable geological and geotechnical conditions on the indicative alignment the slope stability hazards will need to be managed during detailed design and during construction as the actual ground conditions are exposed.

It is envisaged that slope instability (including rock fall hazards) will be managed during construction using a combination of stabilisation and construction management measures. The specific details of the stabilisation measures at any discrete location where a problem manifests will be determined by detailed investigation and design. For the purposes of this appraisal we have considered that some of the suitable treatment options are likely to include the measures presented in Table 12.

In addition, experience from the NGTR project suggests that the risk from slope instability is most effectively managed during construction by careful observation by an experienced engineering geologist to identify landslide hazards when the ground is revealed during excavation and then investigating, developing and installing appropriate mitigation measures as the construction proceeds.

Table 12: Cut slope stabilisation measures

Case	Consequences	Stabilisation Options
Block slide failures in rock	Significant failures of the cutting Regression of cut slope	Sub-horizontal drainage and/or rock anchors likely to be most cost-effective. Excavation and replacement with compacted hard fill (Mid-slope shear key) or shear piles. Buttress fill located at the toe of the slope.
Existing Soil Failures in cutting	Slumping failures of the upper portion of the cutting and regression of cut slope to outside of the proposed designation boundary.	Flatten cut batter to remove landslide mass. Extensive sub-horizontal bored drains combined with surface drainage above landslide and behind the excavation (e.g. counterfort drains). Creation of a mid-slope bench. Vegetation cover to minimise erosion and regression Rock lined cut-off drain located behind crest of cut face to divert surface water runoff.
Adversely dipping soil/rock interface	Sliding of soil in upper profile of cut	Excavation and replacement with compacted hard fill (mid-slope shear key). Horizontal bored drains or more robust counterfort drains to reduce groundwater pressures at the soil/rock interface. Soil nailing or anchoring of unstable areas.
Localised relatively soft soils (often related to high groundwater levels)	Localised failures in soil	Flatten batters locally where possible. Rounding of soil profile at top of cuts. Soil nail stabilisation of unstable areas.
Highly fractured or weathered masses of landslide debris or shear plane exposed in cut slope. Fault or shear zones sub-parallel to slope face.	Significant failures of the cutting. Reactivation of existing landslide mass above cutting. Lateral and vertical ground movements outside of earthworks footprint.	Undercutting to remove the existing landslide masses and basal shear surfaces below road formation levels if possible, and replacement with engineered fill. Soil nail stabilisation of predominantly soil landslide mass. Extensive sub-horizontal bored drains combined with surface drainage above landslide and behind the excavation (e.g. counterfort drains). Anchored bored pile retaining walls. Buttress fill located at the toe of the slope.
Wedge failures along intersecting defects	Medium to large scale rockfall	Localised nailing, anchoring or rock bolting of all identified unstable cut areas. Scale cut-face to remove loose blocks after excavation.
Rock fall due to erosion/unravelling of exposed cut face interbedded sandstone/siltstone)	Progressive regression possibly creating a larger feature	Slope surface protection such as steel mesh pinned to slope or rock drainage ditch/trench. Rock catch ditch and barrier at toe of slope. Rock fall barrier such as “Geobrugg” type rock fall energy absorbing fences in high hazard areas.

8. Embankments

8.1 Embankment design philosophy

Embankment construction will require the placement of large volumes of earthworks fill material. Due to the stresses imparted by the embankment loading, unless specifically treated, weak soils beneath the embankments are likely to shear, settle and consolidate. The Project includes embankments up to 50m above ground level.

A generic suite of designs for embankments in each geological formation that could reasonably be expected to provide the foundation (Pakiri Formation, Alluvium and Northland Allochthon) has been developed to determine stable slope gradients and acceptable levels of settlement according to the general geotechnical conditions anticipated.

Localised or site-specific treatment and additional stabilisation measures will be incorporated during detailed design and construction phases where the revealed conditions demand.

Similar to other earthworks the embankments will be designed for:

- Normal static conditions;
- Earthquake (seismic) loads and secondary effects such as liquefaction;
- Short-term groundwater conditions (storm events); and
- Temporary construction conditions.

The embankment design philosophy has been developed based on the following:

- Precedence from the design, construction and performance of similar roading schemes and major earthworks in similar geological conditions (e.g. NGTR and ALPURT schemes);
- Performance of existing embankments in the local terrain;
- Anticipated geological profile from engineering geological mapping and the preliminary intrusive geotechnical investigations;
- Generic slope stability analyses of critical embankments for an assumed range of geological conditions and physical settings;
- Consideration of route security; and
- Interaction with assumed spoil disposal areas that have been identified within the proposed designation for the Project and adjacent to proposed embankments.

The largest of the embankments are listed in Table 13. The locations of these embankments are shown on the Geotechnical Features Plans (Drawings GT-208 to GT-210).

Table 13: Major embankments along the indicative alignment.

Sector	Chainage	Embankment length along the alignment (m)	Maximum fill above ground level (m)	Maximum embankment slope height (m)
Moirs Hill Road	55300-55720	420	47	47
Moirs Hill Road	54540-55060	520	50	50
Moirs Hill Road	53560-53830	270	36	20
Perry Road	52880-53160	280	20	30

Notes

1. Embankment slope height is the vertical height of a fill slope, taken as the difference in elevation between the toe of the slope and the crest. In sloping topography, the slope height can be much greater (or less) than the embankment height.

8.2 Embankments constructed over Pakiri Formation

The majority of embankments will be constructed over Pakiri Formation.

8.2.1 Ground conditions below embankments

The ground conditions below embankments within Pakiri Formation have been determined by engineering geological mapping within a selection of the gullies that will form the foundations of the embankments. These surveys indicated slightly weathered material is exposed at the base of many gullies, whilst intrusive investigations at the tops of ridges and the upper sides of gullies indicates that the depth to slightly weathered material is between 1 and 20m. Experience at NGTR suggests that the depth to slightly weathered material in gullies generally varies between 2 and 3m with occasional areas of up to 5m depth.

Based on the above information the Project Team has assumed that the depth to slightly weathered material below embankment fills is likely to be at relatively shallow depths at the centre of the gullies and increase with distance from the centre. Furthermore, for the purposes of this concept design and to assess where necessary the size of stabilising shear keys, it is assumed that slightly weathered material occurs from 5m depth. The assumed ground profile is shown in Table 14.

Table 14 Assumed Pakiri Formation weathering profile beneath embankments

Depth (mBGL)	Weathering profile
0 - 2	Residual soil and completely weathered Pakiri Formation
2 - 4	Highly weathered Pakiri Formation
4 - 5	Moderately weathered Pakiri Formation
>5	Slightly weathered Pakiri Formation

The geotechnical parameters selected for each of these weathering layers are those in Table 1.

Underdrainage will be installed within the footprint of the embankments to control the level of groundwater in the soil beneath the fill to maintain embankment stability. For the purpose of this preliminary design the groundwater level has been conservatively assumed to be at natural ground level within the base of the gullies.

8.2.2 Concept design

The concept design for a typical embankment over Pakiri Formation is illustrated on Drawings GT-241, 242 and 243. The embankments typically comprise a central core of engineered fill constructed with a side slope of 1V:2H and a lower strength outer buttress / landscape fill on a side slope gradient of 1V:3H.

Where there is insufficient space from streams or roads the embankments are formed entirely in engineered fill with 1V:2H slopes.

The embankment design includes shear keys, under drains and gully drains. Areas of ‘soft’ material (undrained shear strengths < 80 kPa) within the embankment footprint will need to be removed.

The Project Team has analysed several embankment sizes and geometries ranging from 10m to 50m high with the above configurations. Narrow shear keys extending at least into the moderately weathered material are the most efficient method of achieving the stability design criteria whilst at the same time minimising the quantity of excavation and backfill required (e.g. Figure 14). However, experience from NGTR showed that weak shear surfaces were regularly encountered in the moderately weathered materials and therefore deepening of the shear keys into the slightly weathered rock is often necessary to maintain the required level of stability.

Consequently, for the most part the shear keys are expected to have a minimum width of 10m to provide a practicable and sound connection with the slightly weathered material.

The higher embankments will be constructed with intermediate horizontal, permeable layers of selected durable rock material to aid the dissipation of excess pore water pressure during construction. The preliminary stability analyses subsequently assumes a moderate build-up of excess pore water pressure (Ru = 0.2) throughout the period of construction. Synthetic drainage materials (e.g. Figure 15) are more expensive options should suitable rock material be unavailable. An alternative to the drainage layers would be to incorporate geogrids laid horizontally at appropriate spacings to increase the internal strength of the embankments.

Figure 14: Excavation to beneath weathering zone for shear key on Northern Gateway Toll Road project

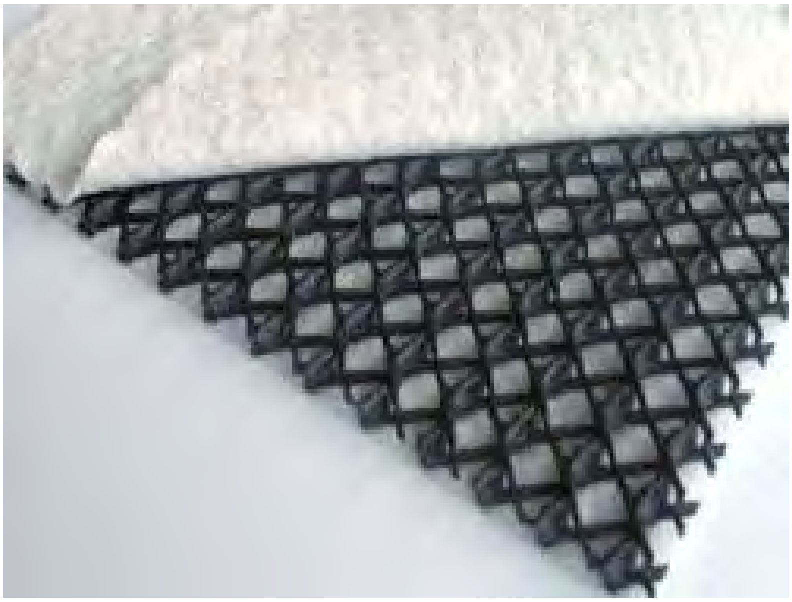


Figure 15: Example of geo-synthetic drainage layer

Settlement of these embankments is not expected to affect their function provided that soft materials are removed from the formations below them and compaction compliance of the embankment material is achieved by adopting normal construction specifications.

Some embankments are to be placed on hillsides where evidence of existing slope instability has been noted during preliminary assessments. The range of potential mitigation options for these areas are discussed in Section 9.

8.2.3 Mechanically Stabilised Earth Embankments over Pakiri Formation

In some locations along the Project it will be necessary to construct steeper embankments (1V:1H or 45° and 1V:0.6H or 60° side slopes) due to physical space constraints.

These steeper embankments will be constructed with mechanically stabilised earth (MSE) slopes as shown on Drawing R-215. These slopes incorporate layers of geogrid placed horizontally as the layers of embankment fill are built up. The MSE slopes will be finished with a grassed slope facing. An erosion protection mesh may be pinned to the slope face to reduce the risk of erosion and establish vegetation if necessary and appropriate. A 60° slope requires the internal geogrid reinforcement to be wrapped around the face of the slope (Figure 16) (or equivalent 'green terramesh' type product used) in order to retain sufficient top soil for the establishment and maintenance stable vegetation.

Figure 16: Example of MSE slope with vegetation under establishment using wrap around geogrid.

MSE slopes are required in the following locations:

- Where the indicative alignment is in very close proximity to the existing SH1 (Ch 59990 to 60280m and Ch 60910 to 61160m).
- Where the indicative alignment traverses across moderately steep ground on split carriageways at different elevations (Ch 56400 to Ch 58800).
- On the approach to bridge and viaduct abutments.

The largest proposed MSE slope is expected to occur at in the area of Hungry Creek (Ch 61100) and has a maximum height of about 18m.

Due to the stresses imparted by the significant embankment loading anticipated by this amount of fill material and depending on the foundation conditions some form of ground improvement or strengthening of foundation soils may be required. This may comprise removal / improvement of any underlying soft alluvial /estuarine deposits or piling through to competent materials. Specific investigation and design will be implemented to identify the extent of these measures at the detailed design stage.

8.3 Embankments constructed over Alluvium

Where identified alluvium layers are relatively shallow (<5m thick) or only present over limited areas within narrow gullies, it would be normal practice to remove the softer material prior to constructing the embankments.

Alluvium is identified to be deeper and /or more extensive in four areas along the route and in these locations it is likely that some form of ground treatment will be required due to its low strength:

- Embankment to the west of Genesis Aquaculture in Perry Road area (Ch 52170 to 52340m);
- Wyllie Road South Embankment (Ch 50000 to 50500);
- Wyllie Road to Woodcocks Viaduct Embankment (Ch 49250 to 50000); and,
- Carran Road Embankment (Ch 48000 to 48660).

The locations of these embankments are shown on the Geotechnical Features Plans (Drawings GT-211 to GT-214.

The ground model assumed for the preliminary assessment of these embankments is provided in Section 5.4.

8.3.1 Stability Analysis

The Project Team has analysed several embankment sizes and geometries ranging from 5m to 15m high and with batter slopes ranging from 1V:2H to 1V:5H. The foundation conditions were based on the above ground model.

The preliminary analyses indicates that the very soft to soft alluvial material identified in the top 5mBGL will not provide a suitable foundation for the fill embankments even for embankments of relatively low heights (5m). Where this case occurs, to satisfy the overall stability of the embankment, improvement of the natural ground will be necessary to approximately 5m depth before construction of the proposed embankment.

Ground improvement or embankment construction options include combinations of:

- Deep-soil mixing (DSM)
- Stone columns
- embankments on pile foundations
- Use of wick drains, basal reinforcement and surcharge loading
- Environmental considerations for ground improvement options are covered in Table 15.

8.3.2 Concept Design

The concept design for embankments over the soft alluvial areas involves ground improvement by deep-soil mixing. This solution meets the slope stability design criteria in the short term condition, long term state and under seismic events (Table 6).

The preliminary liquefaction assessment indicates that liquefaction of the alluvium in the Perry Road and Carran Road sectors is unlikely to be a hazard, consequently additional internal reinforcement of soil mix columns is not required.

Other alternative ground treatment measures such as stone columns or piles could also be used to achieve similarly satisfactory foundation performance.

The concept design for embankments over alluvium (see Drawing R-215) includes a central core of engineered fill with slopes of 1V:2H, with buttress / landscape fill placed on the flanks of the embankment. This approach minimises the volume of well compacted engineered fill required for the central core, whilst at the same time providing the opportunity to accommodate any surplus earthwork materials as landscape fill. Where buttress or landscape fill is placed against the flanks of an embankment for heights of 10m and greater, the underlying ground may also require strengthening.

Table 15 Environmental considerations for geotechnical ground improvement options.

Ground Improvement Options	Description	Environmental Considerations
Deep soil mixing (DSM)	Injection of a binding agent (lime, cement or blends of both) whilst mechanically disaggregating and mixing the soils. In very soft to soft clay soils this typically involves 'dry-soil' mixing of a powder binding agent to create vertical columns or panels of improved strength.	Introduction of binding agents (lime, cement or blends of both) into the ground. Significant cement concentrations are required in wet soils. Changes to local permeability and groundwater flows are restricted to beneath the embankment only. Lime or cement dust during material handling potentially blown by the wind onto adjacent land.
Concrete / Stone columns	'Reinforcing' the natural soil with relatively rigid vertical columns of compacted stone or concrete, which will transmit the load to more competent strata beneath and /or increase the shear strength of the soil.	Vibration during drilling and installation. Increased localised drainage of groundwater by stone columns is restricted to beneath the embankment. Importation of suitable granular material.
Piled embankments	Pre-cast piles driven on a regular grid to transmit load to more competent strata beneath. These are then covered by a load transfer mat comprising granular material and geogrids.	Construction noise of pile installation (e.g. driven piles).
Wick drains and surcharge loading	Pre-fabricated vertical drains installed and preloading of embankment to dissipate pore pressures more rapidly and thereby increase the shear strength and accelerate consolidation of the foundation soil, prior to pavement construction. May not be feasible with tight construction schedules.	No chemical admixtures added to the ground. Changes to local permeability and groundwater flows are restricted to beneath the embankment only.

8.4 Embankments constructed over Northland Allochthon

Fill embankments on sloping ground in Northland Allochthon materials will require extensive shear keys or ground treatment to provide the necessary stability.

There is only one proposed embankment in Northland Allochthon confirmed by the intrusive investigations between Ch 59200 and 59400 near the proposed Hikauae Bidge in the Hungry Creek Sector. Based on the indicative vertical alignment this embankment would be approximately 8m high.

There is a second possible area of Northland Allochthon that has only been identified by geomorphological mapping to date in the area of the Wreaks Road embankment Ch 5760 to Ch 57500.

The locations of these embankments are shown on the Geotechnical Features Plans (Drawings GT-206 and GT-207).

8.4.1 Ground conditions below embankments

The assumed geotechnical parameters for the Northern Allochthon material are as discussed in Section 5.3.3.

The assumed weathering profile for the embankment between Ch59200 and 59400 is based on BH209 and is shown in Table 16 below.

Table 16 Ground Profile for Northland Allochthon Ch59200 and 59400

Depth range (mBGL)	Soil Unit	Soil Type
0 - 4	Residual Soil /Colluvium (soil mantle)	Clayey silt / silty clay
4 - 15	Highly Degraded Northland Allochthon (transition zone)	Clayey silt / silty clay
15+	Moderately Degraded Northland Allochthon (parent rock)	Siltstone

8.4.2 Concept Design

Based on the ground model and assuming an embankment height of 10m a 1V:5H slope gradient has adequate stability provided a deep shear key (or shear piles) is installed into the parent rock material underlying the transition zone. The absence of continuous shear planes in the parent rock which may be adverse for embankment stability will also need to be checked and confirmed during construction.

8.5 Summary of embankment geometries and concepts

Table 17 summarises the main conclusions of the Project Team's assessment of the preliminary concept designs for the embankments based on the anticipated foundation conditions.

Table 17 Embankment geometry and concepts

Foundation Geology	Embankment Height	Embankment Slope Angle (Vertical (V): Horizontal (H))	Additional Stabilisation Measures
Pakiri Formation	0 - 5m	1V : 3H	Removal of material less than 80kPa.
	5 - 50m	1V:2H and 1V : 3H	Shear keys to slightly weathered material, undercuts of weak and compressible soils, horizontal drainage layers within embankment fill, gully drains and under drains.
	0 – 20m	1:1 and 60°	Mechanically Stabilised Earth with "soft" / grass finish and with similar ground treatment to the above.
Alluvium (very soft / soft silt / clay)	5 - 15m	1V : 2H core	Ground treatment comprising deep soil mixing, stone or concrete columns, piles or staged construction with preloading and wick drains.
Northland Allochthon – Mangakahia Complex or undifferentiated.	0 - 10m	1V : 5H	Shear key or shear piles in moderately degraded Northland Allochthon material.
	>10m	Avoided	

9. Existing landslides

9.1 Introduction

There is a significant number of shallow (<5m deep) landslides in the Project area and along the indicative alignment as illustrated on the Engineering Geological Mapping sheets (Drawings GT-101 to GT-115). There are also numerous examples of historic and current instability along the present road network, which have often been initiated after intense or prolonged rainfall events (for example, failures on SH1 cuts around Schedewys Hill and Windy Ridge). Instability commonly occurs on slopes greater than 25° in the Pakiri Formation rocks but can occur on slope gradients of less than 10° where underlain by Northland Allochthon materials.

Several significant or deep landslides have been identified that have a potential effect on the design of the Project alignment (Geotechnical Features drawings GT-200 to GT-215 and Geological Cross Section drawings GT-311 to GT-317). Numerous less significant landslide features that are shallow or relatively small-scale are also expected to be encountered during construction.

Though the deep-seated landslides are predominantly considered dormant or inactive under the prevailing conditions, the lower shear strengths of previously sheared discontinuities[2] and the fractured rock mass commonly encountered in the landslides is likely to control the stability of the cut slopes in these areas. The excavation sequence will therefore require careful planning to control the risk of exposing the shear surface(s) and causing slips to mobilise during construction.

9.2 Generic landslide treatment options

There are many practicable options for managing landslide risks in this type of terrain and the majority of the landslide features recognised along the indicative alignment will be dealt with by the following typical design and construction measures:

- Type 1 - Removal of landslide mass by excavation within the proposed road cutting;
- Type 2 - Removal of landslide mass and replacement with engineered fill (small scale feature);
- Type 3 – Stabilise landslide mass with shear piles or shear key (large scale feature);
- Type 4 - Stabilise landslide with soil nails or ground anchors (large scale feature);
- Type 5 - Placement of retaining structure, for example a cantilevered or anchored bored pile wall (large scale feature);
- Type 6 - Incorporate landslide mitigation within a bridge abutment foundation design (complex interaction with structure); and,
- Type 7 - Placement of fill buttress at toe of landslide feature to counter balance the driving force or re-grading the slope to remove driving force.

Environmental considerations for landslide stabilisation options are summarised in Table 18.

[2] A discontinuity is a plane or surface marking a change in physical or chemical characteristics of a soil or rock mass. Examples include bedding, foliation, fractures, fissures, faults, joints.

Table 18 Environmental considerations for landslide stabilisation

Landslide treatment options (Refer to Drawings GT-301 and 302	Description	Environmental Considerations
Type 1	Removal of landslide mass by excavation within the proposed road cutting	None or minor - earthworks are largely restricted to those required for design cutting.
Type 2 (for small scale feature)	Removal of landslide mass and replacement with engineered fill incorporating drainage measures.	Additional unacceptable material for disposal adds to spoil volumes. Increased importation of drainage materials from off-site.
Type 3 (for large scale feature)	Stabilise landslide mass with shear piles or shear key	Additional earthworks volumes associated with shear key trench and increased importation of granular material. Noise and vibration associated with piling installations.
Type 4 (for large scale feature)	Stabilise landslide with soil nails or ground anchors	Vegetation clearance outside of road earthworks. Minimal disturbance of soil from installation of grout and reinforced bar. Finished soil nailed slopes will be faced – flexible or soft facings such as geotextile or fibrous matting under metallic mesh, soil retention structures or hydroseeding used to assist with regrowth of vegetation. Ground anchors may be finished with hard facings such as pre-cast concrete panels. Noise from drilling for anchors.
Type 5 (for large scale feature)	Placement of retaining structure, for example a cantilevered or anchored bored pile wall	Visual appearance and visibility of finished retaining wall. Noise and vibration associated with piling installations.
Type 6 (for complex interaction with structure)	Incorporate landslide mitigation within a bridge abutment foundation design	Additional earthworks volumes associated with shear key trench and increased importation of granular material. Noise and vibration associated with piling installations.
Type 7 (for small or large-scale feature)	Placement of fill buttress at toe of landslide feature to counter balance the driving force or re-grading the slope to remove driving force. Shear key or piles may also be required.	Additional earthworks volumes associated with buttress fill and excavation for shear key. Additional importation of granular material for shear key and under drainage.

The above generic design or construction measures are illustrated on Drawings GT-301 to GT-302. These measures may be used alone, or in combination, and it is expected to incorporate improved drainage such as counterfort and horizontal bored drains. The installation of increased slope drainage measures may result in very localised drawdowns of groundwater levels within the landslide masses. The extent of drawdown is not expected to significantly extend the zone influenced by groundwater drawdown.

Full and comprehensive geotechnical investigations will be needed prior to construction to confirm site-specific landslide mechanisms and facilitate a detailed geotechnical design to be undertaken.

9.3 Landslides of specific interest

Landslides of specific interest that have been identified as having the potential to impact on the design of the indicative alignment and will demand specific treatment are:-

- Ch 64000 - 64300 Billing Road (Pūhoi Sector)
- Ch 63110 - 63500 Large block landslide at Pūhoi southbound on-ramp (Pūhoi Sector)
- Ch 62940 - 63160 Shallow earth slides and flows at Pūhoi north-bound off-ramp (Pūhoi Sector)
- Ch 59200 - 59220 Schedewys Hill viaduct southern abutment on Northland Allochthon (Hungry Creek Sector)
- Ch 52800 – 53080 North of Perry Road viaduct (Perry Road Sector)
- Ch 52360 – 52760 a network of deep landslides between Perry Road viaduct and the Kauri eco-viaduct (Perry Road Sector).
- Ch 51550 – 51820 Wyllie Road, north of Genesis Aquaculture (Perry Road Sector)
- Ch 48550 – 49050 Carran Road landslides (Carran Road Sector)

The locations of these landslides are identified on the Geotechnical Features Plan (Drawings GT-200 to GT-215) and Geological Cross Sections (GT-311 to GT-317). The Project Team has considered the implications of these landslide features on the route and completed limited targeted borehole investigations during Stage 1 and 2 fieldwork to assess the potential impact and implications of these features on the design of the indicative alignment.

None of the identified landslides present un-manageable obstacles to the indicative alignment. Having identified the locations and scale of the broad mechanisms, there is sufficient information available at this time to confirm the implications of the potential landslide mechanisms and provide confidence that there are practicable design and construction solutions to manage the risk. Selected examples are discussed in more detail in the following sections.

9.3.1 Ch 64000-64300 Billing Road (Pūhoi Sector)

The location of this landslide is identified on Geotechnical Features Plan 2 of 15 (Drawing GT-202) and Geological Cross Section on Drawing GT-311.

The Billing Road area suffers from a widespread network of deep-seated rotational landslides, translational block landslides and earth slides that cover the majority of the south-facing slopes in this location. The indicative alignment includes a 500m length viaduct over the inter-tidal Okahu Creek at heights of around 27 to 28m above creek level. The Okahu Creek valley is partially in-filled with soft unconsolidated intertidal alluvium. There is a possibility that the toe of ancient landslide bodies may extend outwards into the valley and be concealed beneath these estuarine deposits.

Five boreholes were drilled in the Billing Road to Pūhoi Road area during the Stage 1 and 2 geotechnical investigations, which confirmed the geomorphological landslide evidence. The boreholes indicated the landslide blocks, debris and slip zones at various depths down to 10.5m. Figure 17 illustrates an example of a contact between landslide colluvium and the underlying intact rock in this area viewed by the borehole imagery.

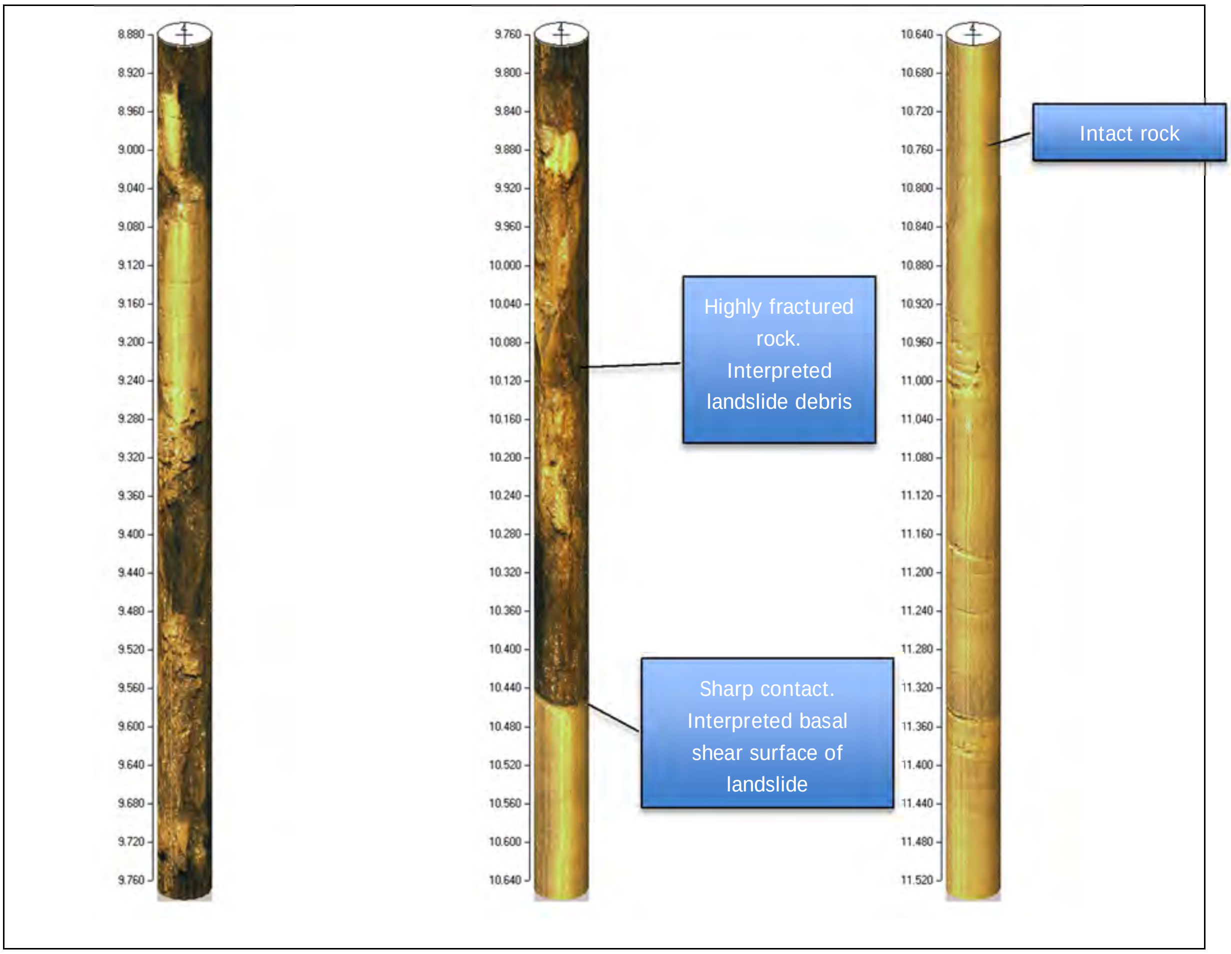


Figure 17: Downhole imagery from BH102 indicating a sharp contact between the landslide colluvium and Pakiri Formation at 10.45mBGL.

The proposed earthwork cuts and the Okahu Viaduct north abutment on the indicative alignment will intercept some of the landslide bodies.

However, inspection of the current vertical and horizontal indicative alignment demonstrates that most of the landslide feature will be traversed over by the viaduct or removed as part of the cutting excavation (Refer to Drawings GT-301 and GT-302 – Treatment Types 1 and 6). Whilst there is the potential for some of the highly fractured and weathered rock mass of landslide debris to be exposed in the cut slopes it is envisaged that this will be managed by further routine earthworks (excavation and re-grading the slope profile).

It is likely that this area will be one location where some groundwater seepage can be expected to occur within the fractured zones and open joints within the landslide mass and therefore additional slope drainage measures may be required.

The Stage 1 and 2 investigations suggest the northern abutment of the Okahu Viaduct is located on the head of a secondary landslide with some evidence of shallow creep. For structural design the abutment will require deep piled foundations into the stable rock mass beneath this landslide. The landslides will be stabilised and piled foundations can be designed to accommodate potential lateral loads from the remaining primary and secondary landslide masses (Treatment Type 6, Drawing GT-302).

9.3.2 Ch 63110-634500 Large block landslide at Pūhoi southbound on-ramp (Pūhoi Sector)

The location of this landslide area is shown on Geotechnical Features Plan 2 of 15 (Drawing GT-202) and Geological Cross Section on Drawing GT-312.

The engineering geological mapping and investigations indicate the head of a potential ancient translational landslide coincident with the indicative alignment. The proposed vertical and horizontal road indicative alignment has the road formation level at approximately RL 20 within the landslide derived colluvium, approximately 2 to 3m above the inferred base of the landslide. Our investigations also suggest the proposed earthworks cut slopes will remove the majority of the head of the landslide. The materials to be excavated may comprise colluvium of highly fractured rock masses.

The proposed earthworks for the indicative alignment in this section will remove the majority of the landslide (treatment Type 1, Drawing GT-301). The excavations for the south-bound on-ramp may expose the basal shear plane towards the toe of the landslide. Additional measures in this area will therefore include slope re-grading to remove the material above the landslide shear surface (Type 2, Drawing GT-301).

9.3.3 Ch 62940-63160 Shallow earth slides and flows at Pūhoi northbound off-ramp (Pūhoi Sector)

The location of this landslide area is shown on Geotechnical Features Plan 2 of 15 (Drawing GT-202) and Geological Cross Section Drawing GT-313.

Through this length, the main carriageway and north-bound off-ramp to Pūhoi are generally located on fill embankments, with a mechanically stabilised earth (MSE) embankment required along the eastern side of the main carriageway to avoid impacts on the existing SH1 alignment.

The embankment will involve placing fill over the toe of slopes with shallow instability, including some active earth flows. Borehole BH105 intercepted colluvium to 3m depth and shallow groundwater levels. The embankment will require significant undercutting and placement of a compacted shear key or shear piles along much of this length to ensure its stability (treatment Types 2 and 3 on Drawing GT-301).

9.3.4 Ch 52800 – 53080 North of Perry Road viaduct (Perry Road Sector)

The location of this landslide area is shown on Geotechnical Features Plan 10 of 15 (Drawing GT-210) and Geological Cross Section on Drawing GT-314. The main landslide back scarp is at the top of the valley slope at about Ch 52800 and appears the result of at least two landslide masses. Both of these landslides join the same gully and lead to a debris run-out zone. Several exposures of moderately weathered rock and borehole BH219 show moderately weathered sandstone and slightly weathered sandstone from 3.5m and 5m depth respectively. All the nearby rock exposures and measurements in the nearby borehole BH219 show bedding is sub-horizontal.

Two further prominent landslide features are observed further to the south-west with the failed debris crossed by the indicative alignment. A significant quantity of groundwater springs to the surface on the slopes and is likely to have been a significant factor in the landslide mechanism. The ground further towards the south west is composed of a series of semi-parallel benches and large hummocks, some slightly back-tilted, but without specific back scarps. The landslide material extends down to the small stream at Ch 53060.

Here, the road is aligned on an embankment just north of the Perry Road viaduct. The embankment tapers down in height, from being approximately 22m height at the viaduct's northern abutment (Ch 53140) to the cut/fill interface at Ch 52880. The embankment is proposed to be built with 1V:3H side slopes.

The upper section of the landslide area is removed by the proposed cutting. The majority of the landslide is outside the footprint of the embankment and the proposed works increase its stability rather than reduce it. However, at lower levels between Ch 52860 and Ch 53060 the embankment crosses side-long ground of the landslide masses and debris.

Preliminary slope stability analyses in the landslide area near Perry Road indicate that significant earthworks involving deep and extensive shear keys (treatment Type 3, Drawing. GT-301) and appropriately placed buttress fill (treatment Type 7, Drawing GT-302) are required to ensure that the additional load introduced by the embankment does not reactivate the existing landslides. The results indicate the embankment to be stable under the loading conditions considered (both static and seismic conditions) provided that shear keys penetrate the colluvium and basal shear surfaces and are installed into the competent slightly weathered Pakiri Formation rock. Shear key depths will be increased if colluvium material extends deeper than assumed or if pre-existing shear surfaces are encountered.

The concept design allows for shear keys for the stabilisation of the landslide to be continued for the full extent of the embankment to the north (Ch52860). It is unlikely that further specific stabilisation measures will be required, but this will be confirmed by further detailed investigations and analyses for detailed design.

9.3.5 Ch 52360 – 52760 Series of deep landslides between Perry Road viaduct and the Kauri eco-viaduct.

The western side of the ridgeline between chainage 52360 and 52760 hosts a series of deep landslides, extending from near the ridge crest to the stream in the base of the valley. The upper and relatively steeper slopes nearer to the ridge crest display some active instability. The location of these landslides are shown on Geotechnical Features Plan 11 of 15 (Drawing GT-211) and Geological Cross Section Drawing GT-315.

The landslides appear to have formed at a contact between relatively weaker and relatively stronger units in the rock mass underlying the ridgeline - potentially along a gently inclined sharp weathering contact as observed in the surrounding boreholes BH219 and BH220.

For the majority of this section the road is aligned in cut beneath the landslide masses and removing the main stability hazard. However, a 200m length of the road is formed in embankment over a landslide.

A preliminary slope stability analysis of the embankment crossing the landslide was carried out, assuming a broadly translational landslide of 8m depth below ground level and a low strength shear surface similar to soft, extremely weak bedding-parallel clay seams that are identified in other landslide zones in Waitemata Group rocks in the Auckland Region (East, 1974; and Williams et al, 2004). The results indicate the embankment to be stable under the loading conditions considered (i.e. both static and seismic conditions) provided that multiple shear keys are installed to beneath the pre-existing shear surface (e.g. shear keys of 3 to 6.5m width and up to 8.5m depth over the length of the landslide; Figure 18) (e.g. treatment Type 3, Drawing GT-301).

The dimensions of shear keys are indicative only and more detailed modelling/investigations will be required for detailed design.

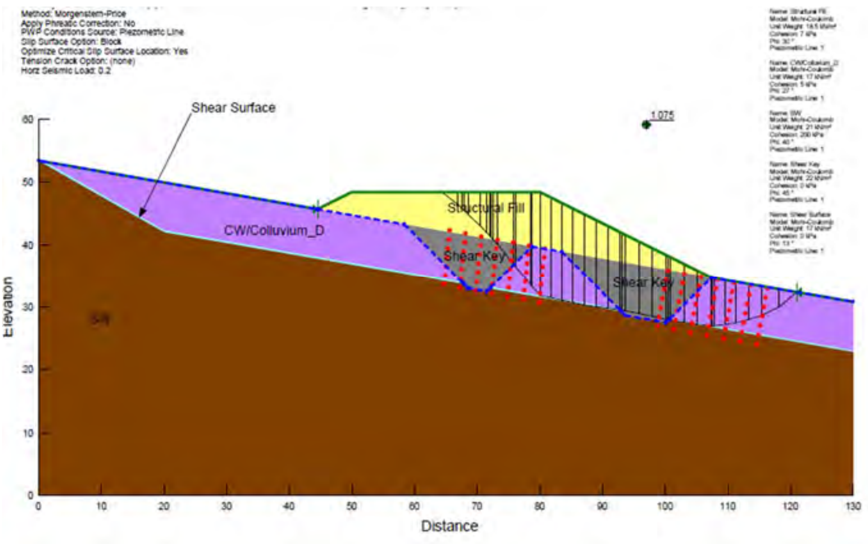


Figure 18: Indicative design concept for embankment crossing existing landslide south of Kauri Eco-Viaduct.

9.3.6 Ch 51550 – 51820 Wyllie Road, north of Genesis Aquaculture (Perry Road Sector)

This area is characterised by two separate landslide zones, shown on Geotechnical Features Plan 11 of 15 (Drawing GT-211). The indicative alignment crosses the head of a smaller landslide mass at Ch 51720-51820. The indicative alignment also crosses at or below the toe of a large landslide at Ch 51550-51700.

Ch 51720-51820

The indicative alignment predominantly crosses the head of this landslide in full cut approximately 16m depth below the existing ground level. The indicative alignment is well below the expected basal shear surface of the landslide and the excavations associated with the cutting will remove the top of the landslide hazard.

Bedding parallel shear zones are identified in BH114 nearby. They are likely to have much lower residual shear strengths and if present and exposed in the large cut slope face, they may provide release mechanisms for planar failures to develop.

Ch 51550-51700

This landslide was crossed by earlier alignments under consideration and was investigated by the preliminary borehole investigation. Borehole BH114 confirmed the highly disturbed characteristics of landslide debris and revealed voids and small cavities formed in the landslide mass. Borehole camera imagery identified a shear zone from 8.8m that extended to a depth of 9.4m. The shear zone was interpreted to be inclined towards the north-east at approximately 11°.

The bedding plane characteristics measured by the downhole imagery below 9.5mBGL suggest the bedding is generally gently dipping (5-19°) towards the north to northeast – parallel to the basal shear surface of the landslide. The downhole imagery suggests that the moderately weathered Pakiri Formation below 9.5m depth has not been disturbed.

Geological Cross Section Drawing GT-316 shows the interpreted landslide extent at BH114.

Subsequent to the geotechnical appraisal and investigation, the road has been realigned to cross below the toe of the landslide and on an alluvial fan on an embankment of typically 7.5m height.

The embankment may require deep and extensive shear keys (treatment Type 3, Drawing. GT-301) to ensure that the additional load introduced by the embankment is stable over existing colluvium or alluvium, in a similar manner to the design required for the embankment north of the Perry Road viaduct (refer to Section 9.3.4). The embankment is expected to be stable under the loading conditions considered (i.e. both static and seismic conditions) provided that shear keys penetrate any colluvium, weak alluvium or basal shear surfaces and are installed into the competent slightly weathered Pakiri Formation rock. Shear key depths will be increased if colluvium material extends deeper than assumed or if pre-existing shear surfaces are encountered.

10. Structures

10.1 Retaining Walls

Retaining walls are included in the indicative design in three general areas:

1) Adjacent to the rediscovered Pā o Te Hēmara Tauhia, just north of Billing Road (see Geotechnical Features Plan, Drawing GT-202);
2) At Hungry Creek (see Geotechnical Features Plan, Drawing GT-205, and Typical Cross Section Drawing R-016); and
3) In several locations along the realignment of the existing Moirs Hill Road (see Geotechnical Features Plan, Drawing GT-207).

To limit the impact of a cut slope and protect the lower terrace of the Pā o Te Hēmara Tauhia site, a 45m long retaining wall is proposed in the upper portions of the cut. The retaining wall has a maximum height of approximately 5m and may take the form of a soldier pile wall (vertical steel or concrete piles with horizontal timber, steel or concrete lagging). Further detailed investigations may show a soil nailed slope is adequate instead of a retaining structure.

The concept design of the retaining wall at Hungry Creek is a bored concrete piled retaining wall to provide a robust solution to stabilise the proposed embankment without placing additional load on the existing degraded road cutting above State Highway 1. A piled concrete retaining wall is designed because of the space constraints in this area and to provide route security against a slope failure that could otherwise affect both the new and old roads. The bored concrete pile wall is in a position where it can be screened with vegetation and/or faced with appropriate materials (brick, stonework) to be sympathetic to the environment.

Small retaining walls have been designed where the existing Moirs Hill Road is realigned or widened across the head of steep gullies with some existing evidence of shallow instability. Retaining walls limit the additional load placed on potentially unstable material within the gullies, and limit the footprint of the works. These retaining walls have been designed as wooden palisade walls to be sympathetic to the local environment.

The final form of these retaining walls will be dependent on the ground conditions found following detailed ground investigation, particular site constraints, cost and landscape requirements. There are innumerable alternatives such as anchored panel or concrete cantilever walls, gravity structures and bored or driven free-standing or anchored piles.

Retaining walls can be designed to allow for sufficient lateral load capacity to resist local movement of the slope and be founded at a depth below the influence of any slope instability. Standard solutions for all retaining walls are routinely designed to achieve structural serviceability by limiting the wall lateral movement.

10.2 Viaduct and Bridge Foundations

Due to the scale of the structures and loads applied from bridge abutments and piers shallow foundations are often considered to be inefficient. Piled foundations or other stiff load bearing inclusions are more often preferred to transmit loads down to underlying competent rock such as moderately weathered Pakiri Formation.

These foundations will be constructed of reinforced concrete and will be detailed to provide high levels of ductility. Ductility will enable these components to absorb high earthquake induced forces from the superstructure and potential ground movements in any overburden soils.

Piles supporting the bridge abutments and piers of similar scale to those proposed for this route were constructed in largely identical conditions for the NGTR project immediately to the south. It is highly likely that similar large diameter bored piles in the underlying competent Pakiri Formation rock will be adopted for this Project for the following reasons:

- The reliable capacity that can generally be achieved for piles founded on bedrock;
- The need to socket the piles into bedrock to achieve adequate lateral resistance for earthquake and lateral loads; and
- A small number of larger piles is generally considered more efficient where access is constrained in steep-sloped terrain.

Foundations will be designed in accordance with standard practice and in particular the NZTA Bridge Manual.

Where the bridge piers and viaduct abutments are located on existing landslides (for example, the northern end of Okahu Viaduct), the design philosophy includes:

1) Stabilisation of the landslide mass, through the use of excavation, shear keys, shear piles (methods of Viggiani, 1981 and Chmoulian, 2004), anchors and additional drainage (refer to Section 9.2).
2) Deep piled foundations extending into underlying stable rock mass and sleeved with large diameter casing to isolate the structure from ground displacements.
3) Pile casings and piles designed to accommodate potential lateral loads.
4) Where such measures are necessary, the degree of separation and isolation of the structure shall be designed to accommodate the cumulative displacement effects of at least two successive design earthquakes.

11. Earthworks

11.1 Excavatability

Ease of excavation assessment is generally governed by rock strength and rock mass defect spacing as suggested in published rock excavatability assessment methods such as Pettifer and Fookes (1994).

The geological long section (Drawings GT-151-161) presents a broad summary of material excavatability with an anticipated location of blasting. It is expected that the residual and weathered soils of the Pakiri Formation will be readily excavated by conventional earthmoving plant. The moderately and slightly weathered Pakiri Formation becomes increasingly difficult to rip or excavate and experience from NGTR would suggest that controlled blasting improves production.

The Project Team has made a preliminary assessment of the excavation potential of materials within the cuts based on

- The borehole records (showing fracture spacing and field strength estimates),
- The laboratory Unconfined Compressive Strength test results; and
- Experience and records from the NGTR earthworks construction.

The Project corridor spans a series of highly variable geological domains with various dipping strata and structures consequently excavatability conditions can be expected to change over relatively short distances.

Unweathered Northland Allochthon rocks can be expected to be ripped similar to highly weathered Pakiri Formation.

Table 19 provides a summary of the general excavatability characteristics of the materials to be encountered along the Project.

Table 19: Summary of anticipated excavation methods

Geology		Anticipated excavation method
Pakiri Formation	Completely to moderately weathered	Conventional dig / rip
	Slightly to unweathered	Blasting for economical excavation
Northland Allochthon Mangakahia Complex or undifferentiated		Conventional dig / rip
Alluvium / Colluvium		Conventional dig

Figure 19: Breaking of Slightly Weathered Pakiri Formation rock following production blasting (NGTR construction, NGA).

11.2 Material suitability

The bulk fill materials required for the construction of the embankments along the indicative alignment will be sourced from the excavations in the Pakiri Formation terrain. The preliminary assessment of earthworks volumes based on the proposed vertical and horizontal predicts that there will be an excess of spoil generated over the whole route – there is a larger volume of material to be excavated than is required for construction.

Based on experience from NGTR, which was constructed in similar terrain and geological materials, a significant proportion of the residual soils excavated from cuts in the Pakiri Formation (30-40% of the cut material other than rock) will be too wet for practical compaction (>5% wet of optimum moisture content) without pre-treatment and has poor compaction and strength qualities. It is anticipated therefore that this material will be cut to waste or used as landscape fill.

The weak and occasionally moderately strong weathered Pakiri Formation rock is generally suitable for re-use as structural fill and preliminary estimates suggest that there will be an abundance of this material.

Slake durability testing has shown that the mudstone and closely inter-bedded mudstone / sandstone materials are not sufficiently durable to be used as a high void rock fill material (Opus, 2002) but the demand for this quality of fill on the indicative alignment is limited. Where thick beds of stronger sandstone are encountered it can be separated and stockpiled for use as a higher strength, high void rock fill material in shear keys or as intermediate embankment and spoil disposal drainage layers.

The residually and completely weathered volcaniclastic Pakiri Formation soils (silty clay, silty sand and sandy silt) are typically wet of their Optimum Moisture Content and present some difficulties with their handling and re-use. To be used as compacted fill these soils may be dried (if large fill areas are available for drying) or stabilised with lime or cement to expedite the earthworks.

The size of the embankments and the underlying foundation conditions in the base of the gullies (colluvium and wet organic rich alluvium or residual soils) will likely require extensive undercuts and shear keys. Most of the undercut materials will be unsuitable for fill operations and placed in allocated spoil disposal areas.

11.3 Compaction

Experience from previous investigations and major earthworks schemes around the Auckland Region (e.g. NGTR, Schedwys Hill investigations, SH20 extension) provide confirmation of the suitability and general compaction characteristics for similar Waitemata Group / Pakiri Formation materials.

The moderately strong Pakiri Formation rock will be required to be broken down for placement as a fill and significant effort and processing may be required to break down the rock to achieve the required air voids specification.

Compaction tests on crushed Pakiri Formation rock by Opus (2002) suggest the rock may on average require wetting up by about 2% to 3%. Opus also identify the risks associated with over-wetting and consequential under compaction (air voids >10%) resulting in a decrease in compacted strength.

Compaction testing and experience from NGTR and others in Pakiri Formation materials (Opus, 2002) indicates a volume decrease (from both bulking and compaction effects) in the order of 5-15% is applicable for direct cut to optimally compacted fill for Pakiri Formation soils. Similarly, compaction testing and experience suggests a volume gain (from both bulking and compaction effects) in the order of 6-20% for rock materials. An overall volume gain of 10-20% is applicable for unsuitable materials requiring disposal.

The Project Team have relied upon these established precedents in the assessment of construction earthworks balance, material handling logistics and practicable sequencing for construction as outlined in Section 6 of the AEE document.

12. Spoil disposal

12.1 Spoil disposal philosophy

A philosophy for the disposal of surplus materials (including both excess material from the earthworks balance and materials considered unsuitable for re-use) was developed between the key design and environmental personnel in the Project Team.

The spoil disposal philosophy includes the following key elements:

- The indicative alignment has been split into a number of construction zones, generally separated by main bridges and viaducts (refer to the Section 6 of the AEE document). Surplus spoil generated in each zone should, if possible, be disposed in that construction zone.
- Spoil disposal sites have been identified alongside or close to the indicative alignment, which do not pose a hazard to the motorway, surrounding infrastructure or landowners.
- Adequate capacity has been identified to dispose of total anticipated spoil volumes within the proposed designation.
- Known areas of significant landsliding have been avoided where possible.
- Landscape and environmental factors have been considered in the site selection process to minimise environmental impacts (refer to the Project Landscape and Visual Assessment Report).
- Landscaping and drainage factors will be considered in the detailed design of indicative spoil sites to more closely resemble the natural landscape.
- On-site disposal will be used where possible by use of landscaping fill and placement of non-structural fill on the flanks of the fill embankments to achieve flatter slope batters.
- Use of embankments in place of structures to support the indicative alignment where practicable and cost-effective.

Additional geotechnical considerations

Additional geotechnical considerations for spoil disposal have also included:

- Slope stability of the placed spoil. Disposal sites need to be founded on competent materials or appropriate design solutions are identified.
- Spoil sites designed such that they will not impact on the stability of road embankments from additional loads or surcharge.
- The assessment of landslide risk on the surrounding topography and the impact or benefit of placing spoil on slope stability.
- Adequate surface and subsurface drainage provisions are applied (refer to the Project Operational Water Assessment Report).
- The placement of highly sensitive and wet materials behind properly engineered and constructed containment bunds.

12.2 Selection of potential disposal sites

Potential spoil disposal sites were identified by a joint iterative process between the design and environmental specialists. The selection process involved the following activities:

- The geotechnical team developed a 'long-list' of potential spoil disposal sites taking into account the terrain and geotechnical conditions assessed during the geotechnical appraisal mapping work.
- Approximate storage volume estimates of the long-list spoil disposal sites were calculated.
- Design and environmental specialists (including landscape, ecology, sediment and erosion control, stormwater, constructability and geotechnical specialists) independently assigned ratings to each long-listed location.
- The approximate distribution and volume of surplus materials was identified based on the earthworks balance, construction methodology and sequencing. The volumes included estimates of unsuitable materials resulting from undercuts, shear keys, landslide treatments etc.
- An option analysis was completed for all long listed locations and a short-list of spoil disposal locations selected.
- A workshop was held between design and environmental specialists to critically review the short-listed sites. The workshop included personnel with experience and lessons learnt from the NGTR.
- Potential spoil disposal sites were selected with a capacity to meet the current estimate of surplus spoil.
- Field visits were carried out to assess and confirm the geotechnical suitability of the selected sites.
- Locations and their extents were reanalysed during evolution of the design and earthworks.

Large sections of the proposed designation are highly constrained or unsuitable for spoil disposal options due to:

- Close proximity to the existing SH1;
- Close proximity to main rivers and drainage channels located below the indicative alignment;
- The indicative alignment traversing steep valley sides where spoil disposal would require significant engineering measures;
- Areas underlain by Northland Allochthon materials that are notorious for their slope instability and would require considerable stabilisation measures;
- Areas with existing significant landslides which may be reactivated by spoil loading;
- Areas with very soft foundation soils which will require significant ground treatment prior to spoil disposal; and
- Susceptibility to erosion and/or flood hazards.

12.3 Spoil disposal sites

As a result of the identification and selection process, a number of indicative spoil sites have been identified to dispose of the surplus earthworks materials. These are shown on Drawings R-101 to R-115. Spoil site No. 10 just north-east of Moirs Hill Road in the forested area is the largest of the sites, with a capacity of some 1.5Mm^3. A concept design for this location is presented in Drawing GT-244.

The majority of the spoil disposal areas identified are located close to the indicative alignment and involve extensions to the upstream sides of embankments and the infilling of gullies above the road. These often require considerable design and drainage measures to avoid any discharge of sediments onto the road or blocking of culverts. Refer to the Construction Water Assessment and Operational Water Assessment reports for the assessment and management of surface water and erosion aspects.

Landscape fill sites have been identified where large embankments can be widened with non-structural fill over relatively flat ground.

12.4 Geotechnical design concepts for spoil disposal

Concept designs have been prepared for two spoil disposal sites to demonstrate the general geotechnical feasibility.

A. Site SL10. This site was selected due to its large size (the largest disposal site at approximately 1.5Mm3). The concept design is illustrated on Drawing GT-244.

B. Site SL3 (Ch 61720-61940). A concept design has been prepared to illustrate the geotechnical stabilisation and underdrainage of a high embankment with spoil placed in the gully upstream of the embankment (Figure 20). The concept design is illustrated in Drawings GT-241 to GT-243.

The concept designs include the following geotechnical elements:

- Shear keys constructed beneath the road embankments. Shear key depths and widths vary for various heights of embankment and foundation conditions. Shear keys are required to be slightly embedded into moderately weathered Pakiri Formation rock.
- Underfill drains are required to be excavated to control the level of groundwater in the ground beneath the spoil and gully drains connected together to convey the water from beneath the road at the lowest point.
- Separate spoil bund(s) constructed to separate the road construction work area from the spoil disposal in the early stages to minimise the load from spoil on the road embankment.
- Horizontal drainage layers placed to control pore pressures in the spoil embankment during construction.
- It is anticipated that the major embankments will be fully instrumented to monitor pore water pressures, settlements and lateral displacements during construction.

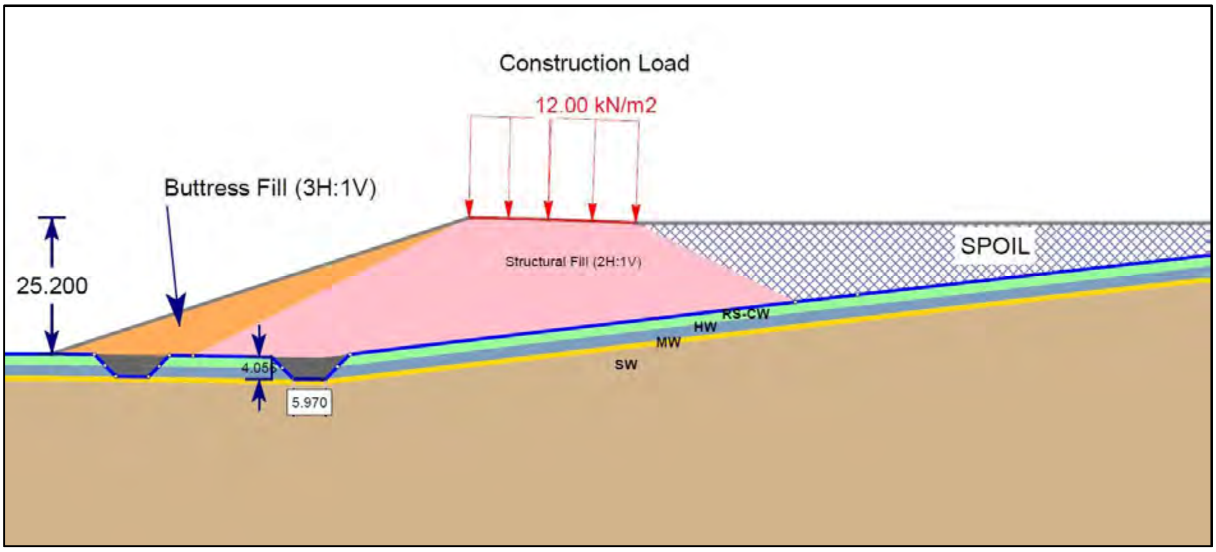


Figure 20: Schematic illustration of spoil location SL3

The concept designs have been developed to demonstrate feasibility and assess impacts. The detailed design will be dependent on several factors, including:

- Detailed site investigations
- The programme of road embankment construction in relation to the spoil area filling;
- The timing of unsuitable material being excavated and where it is located;
- The timing of excavation and available material that could be used for construction of the containment bunds, drainage layers and shear keys;
- The properties of the materials to be disposed;
- The contractor's preferred access and haul road layout;
- Temporary surface water drainage and sediment control layout; and,
- The type of earthmoving plant selected by the contractor.

13. Ground settlement

13.1 Settlement of the ground due to the increase loading from embankment

Settlement of embankments founded on Pakiri Formation is unlikely to be significant as the formation is stiff and relatively incompressible.

Where embankments are founded in areas with thin deposits of soft ground or alluvium it would be normal practice to remove the compressible materials and largely eliminate the settlement risk.

Where alluvium is thicker and /or more extensive (such as indicated in the alluvium areas of Woodcocks Road and Carran Road in the Carran Road Sector) and it cannot be removed the placement of the embankment will result in some settlement. Immediate settlements are expected to take place during or immediately after construction of the embankment but consolidation settlements are expected to take several months or years. The use of wick drains and preloading can be used where possible to accelerate settlement if necessary.

In order to mitigate the effects of predicted settlement some other forms of ground improvement such as stone columns, piles or soil-cement mixing may be needed. Design of these ground improvement measures depends upon the site specific geotechnical properties the expected settlement magnitude and the horizontal and vertical extent of the potentially compressible layers.

Based on the investigation data to date, a preliminary ground treatment solution involving deep soil mixing beneath the fill has been demonstrated to limit the total settlement to acceptable margins in the softer alluvial areas of Woodcocks Road and Carran Road.

The design of ground improvement to treat embankment settlement will be based on the serviceability criteria for the route and there will be no significant impact or effect on adjacent facilities or structures.

13.2 Settlement of the ground due to groundwater lowering

Groundwater is expected to be lowered in some places due to the excavation of the deep road cuttings and associated slope drainage measures. Lowering the groundwater levels will result in decreased pore water pressures and an increase in the effective stress applied by the overlying materials. Depending on geology and amount of groundwater drawdown this can lead to a settlement of the ground surface.

The Hydrogeology Assessment Report and Drawings ES-101 to ES-117 present the predicted groundwater drawdown contours based on the depth of cutting excavation and existing ground water level.

In relation to lowering of the groundwater due to the road cutting excavations of this Project:

- Many of the cuts are predicted to be formed above the groundwater level and thus will have no discernible impact on the groundwater table.
- Drawdown is very localised to the areas of cuts along the indicative alignment. The maximum predicted drawdown is about 25m directly at the cut location, but is typically in the order of 4-10m. In the worst case there is a drawdown effect of 0.1m extending to a distance of about 700m from the indicative alignment centreline. However, groundwater drawdown of any significance (i.e. say 5m or greater) is constrained to within 160m of the indicative alignment.

- The predicted groundwater drawdown extends to only a very limited number of existing buildings, structures and utilities (infrastructure) that are not removed completely by the road construction. The predicted drawdown at these locations ranges from <0.1m to <5m. In many situations, the predicted drawdown is within the expected range of natural groundwater fluctuation.
- Groundwater drawdown is, for the most part and for all of the cases where it extends to any structures, predicted to be limited to groundwater levels within the relatively strong rock formations (MW-SW Pakiri Formation) that have very low compressibility.
- Minor groundwater drawdowns in the rock beneath or in the vicinity of structures will not result in settlement of the surface soils.

To assess the impact of settlement on infrastructure, we completed a two-stage screening process:

1) In the first stage, the predicted groundwater drawdown contours were overlain with locations of known infrastructure and assets. Areas without any existing infrastructure were screened out. Locations with groundwater drawdown <1.0m in the vicinity of existing infrastructures were also eliminated in this stage.
2) Ground surface settlement using one dimensional compression theory was considered to determine anticipated effects.

No infrastructure or assets were identified that were considered to be at risk of experiencing settlement as a consequence of groundwater drawdown.

14. Geotechnical risk management

The engineering geological model described in Section 5 has been created from:

- Desk studies and observations from engineering geological mapping of the indicative alignment and surrounding area;
- Knowledge of the geological environment and materials from the design and construction of other major earthworks and natural exposures in the Auckland Region. Significant observations of the Pakiri Formation weathering, material properties and strength characteristics are provided by construction of the NGTR, directly to the south of this Project; and
- Preliminary geotechnical investigations carried out along the indicative alignment to date.

The engineering geological model includes a conservative generic weathering and strength profile for the Pakiri Formation for road cuttings (Section 5.1).

The model provides the basis for the design and assessment of cuttings and excavations that has been developed and the associated assessment of effects. Detailed investigations and designs will need to be carried out and site-specific ground models will be developed to refine the design further, however, in the meantime some consideration has to be given to the implications or impact of the ground model varying across the site.

The depth of the weathering profile strongly influences the scheme metrics. For example, the revealed weathering profiles will dictate the final cut slope profile adopted for stability as well as the characteristics and relative proportions of the re-usable engineering materials or unsuitable material that has to be cut to waste.

To date there are twenty six machine drilled boreholes on the indicative alignment that provide specific data points where the weathering profile in the Pakiri Formation can be identified. The only location where the revealed weathering profile was found to be deeper than the generic model was immediately north of Moir's Hill, where a group of closely located boreholes confirmed a greater depth of residual soil.

The specific implications of this finding have been incorporated into our assessment of effects and the proposed designation width adopted in this location will accommodate the anticipated conditions. Elsewhere along the route, whilst the expectation is that the ground conditions will be better than assumed (a more stable, less weathered profile than the generic model) the proposed designation width has incorporated a buffer beyond the earthworks footprint dictated by the preliminary design resulting from the generic weathering profile model.

The assumptions in the generic geological weathering profile (Table 8) are an example where the Project Team has considered the range of environmental conditions that could be encountered along the indicative alignment and, with limited supporting factual data, assessed the likely impacts on design and the construction footprint.

The philosophy adopted reduces the risk that the overall geotechnical-related effects over the whole route will not be greater than predicted at this time – accepting that in some specific circumstances and locations there will be local "outliers" where the geological / geotechnical conditions are worse than assumed and specific additional treatment or mitigation maybe required.

Given the scale and complexity of the Project a comprehensive summary of all the risks and opportunities that exist as a consequence of the geological and geotechnical uncertainties is significant. However, Table 20 below provides a broad indication of how the Project Team has addressed the risk / opportunity to date for this stage of the Project evolvement and to ensure that during the actual Project delivery there are few, if any, unpleasant, unforeseen geotechnical issues.

The main geotechnical risk to the Project is in relation to variations in ground conditions from the current model, and their effect on cut volumes and surplus materials. The single most important means of mitigating ground risk, or taking advantage of the opportunities, and removing geotechnical uncertainties from the Project will be the execution of the additional ground investigations.

Table 20: Management of geotechnical risks and opportunities

Geotechnical Uncertainty	Risks / Opportunity	Qualitative Rating	Strategy adopted by Consent Design	Future Mitigation
Depth / thickness of Pakiri Formation weathering is under-estimated	Earthworks increased and road easement has to be wider to accommodate greater depth of low strength materials cut at shallower slope angles	Low Risk	Conservative geological model established for consent design. Any variation can be accommodated within the proposed designation.	Additional site investigations and testing
	Increased volume of cut and greater surplus of material requiring disposal	Low Risk	Conservative geological model established for consent design. On-site spoil disposal areas identified to accommodate estimated volumes.	Additional site investigations and testing
	Increased volume and/or greater proportion of unsuitable material to be cut to waste	Moderate Risk	Relative proportions of unsuitable material in cut volumes based on factoring the experience from NGTA. On-site spoil disposal areas identified to accommodate estimated volumes.	Additional site investigations and materials testing. Potential to re-use unsuitable materials by treatment with cement / lime stabilisation.
	Shear keys / ground treatment to stabilise embankments are deeper and larger.	Moderate Risk	Estimated earthworks volumes include conservative shear key depths to accommodate some variability.	Additional site investigations and testing
	Foundation depths for bridges / viaducts are deeper. Economic impact due to additional costs for deeper foundations.	Low Risk	Foundation concept is unlikely to vary to the extent that there is any change to environmental effects. Consent design accommodates risk.	Additional site investigations and testing
	Reduced quantity of SW material in deep cuts requiring blasting	Low Opportunity	Conservative geological model established for consent design and assessment of excavatability characteristics. Locations of anticipated blasting is unlikely to change significantly.	Additional site investigations and testing

Geotechnical Uncertainty	Risks / Opportunity	Qualitative Rating	Strategy adopted by Consent Design	Future Mitigation
Depth / thickness of Pakiri Formation weathering is over-estimated	Earthworks reduced and road easement is narrower than consent design. Larger buffer to proposed designation boundary.	Moderate Opportunity	Conservative geological model established for consent design so anticipate reduced footprint.	Additional site investigations and testing
	Reduced volume of cut in cut to fill balance equation	Moderate Opportunity	On-site spoil disposal areas identified to accommodate greater volumes from a generic ground model	Additional site investigations and testing
	Reduced volume and/or smaller proportion of unsuitable material to be cut to waste	Moderate Opportunity		Additional site investigations and testing
	Shear keys / ground treatment to stabilise embankments are smaller or not required.	Low Opportunity	Earthworks volumes include conservative shear key depths to accommodate some variability.	Additional site investigations and testing
	Foundation depths for bridges / viaducts are shallower and less expensive.	Moderate Opportunity	Other foundation concepts potentially viable.	
	Greater quantity of SW material in deep cuts, requiring extra blasting	Moderate Risk	Locations of anticipated blasting is unlikely to change significantly.	Additional site investigations and testing
Alignment impacted by unidentified landslide	Realignment or change to proposed designation required to ensure route security and mitigate the impact of the landslide on the route. Escalation of construction costs.	Low Risk	Engineering geological appraisals and mapping to identify key landslides. Qualitative risk assessment for short-listing of indicative alignment options to minimise landslide risks. Preliminary geotechnical investigations to confirm main landslide locations. Designation accommodates some scope for realignment to minimise impact should unforeseen landslides be encountered.	Review of landslide hazard and risk at future stages of the project. Split grade carriageways to reduce vulnerability. Additional site investigations as early as possible to identify unexpected conditions.

Geotechnical Uncertainty	Risks / Opportunity	Qualitative Rating	Strategy adopted by Consent Design	Future Mitigation
	Potential for destabilisation of landslide. Escalation of construction costs.	Moderate Risk	Designation commensurate with terrain and environmental constraints. Designation accommodates some scope for realignment to minimise impact should unforeseen landslides be encountered.	Avoid landslide, extend earthworks measures to remove risk, or develop specific slope stabilisation engineering measures. Additional site investigations and monitoring (inclined inclinometers, survey points, sensors).
Alignment on unidentified Northland Allochthon	Route security compromised and realignment required. Change to proposed designation and/or land take.	Low Risk	Engineering geological mapping and terrain evaluation undertaken to identify risk areas. Any variation can be accommodated within the proposed designation.	Additional site investigations early in design programme.
	Consent design concepts not applicable. Shallower cut slope batters required for slope stability. Additional slope stabilisation measures.	Moderate Risk	Engineering geological mapping and terrain evaluation undertaken to identify risk areas. Any variation can be accommodated within the proposed designation.	Additional site investigations early in design programme. Additional earthworks treatments within existing easement.
Poor ground characterisation or unidentified alluvium / soft soils.	Additional undercut / ground treatment / foundation strengthening / shear keys. Failure/increased settlement of embankments. Increased construction costs.	Moderate Risk	Conservative assessment of extent and depth of alluvium adopted from limited preliminary geotechnical investigations. High level design assessment of areas requiring ground treatment to accommodate variability.	Additional site investigations.
Significant adversely-oriented geological structures (shear zones, bedding parallel clay seams, persistent	Slope failures where adverse in exposed excavations. Increased depth of shear keys for embankments. Localised areas that need additional	Moderate Risk	Engineering geological mapping to identify bedding dip direction local to cuttings. Downhole optical televiewer logging of boreholes to identify main structure. From NGTA experience,	Develop site-specific design solutions including retaining walls, rockfill buttresses, and reinforcement with rock anchors. Localised additional drainage. Additional site

Geotechnical Uncertainty	Risks / Opportunity	Qualitative Rating	Strategy adopted by Consent Design	Future Mitigation
defects) not identified.	support.		conservative shear key depths adopted to accommodate some variability.	investigations prior to detailed design. Laboratory shear strength tests of defect surfaces (e.g. shear box, ring shear tests). Engineering logging of cut slopes during construction
Poor site-specific knowledge of groundwater conditions and fluctuations.	Design slope stability criteria not satisfied over time. Unexpected groundwater seepages from cuttings.	Moderate Risk	A hydrostatic groundwater profile has been adopted to check global stability of slopes. Sensitivity analyses performed for slope stability analyses of concepts.	Regular groundwater monitoring in installed piezometers over a period of time. Inspections of groundwater seepage during and following excavation. Implement site-specific design solutions. Install additional drainage measures.
Poor knowledge of site-specific fracture zones. Unexpected groundwater seepages from cuttings.	Erosion on slope faces. Localised instability.	High Risk	Rock fall catch ditch accommodated in consent design for all rock cut slopes.	Inspections of groundwater seepages and rock fall hazards during and following excavation. Additional drainage measures implemented.
Mechanisms and characteristics of landslides poorly understood.	Slope failures during and post-construction.	Moderate Risk	Identify range of feasible design solutions for current knowledge.	Additional detailed site investigations of mechanisms and extents of specific landslides. Installation and monitoring of slope movement indicators (e.g. inclinometers, survey points, sensors). Develop site-specific slope stabilisation engineering measures.

Geotechnical Uncertainty	Risks / Opportunity	Qualitative Rating	Strategy adopted by Consent Design	Future Mitigation
	Alternative structural and earthworks designs (e.g. shortening of viaducts, improved foundation stability).	Moderate Risk or Moderate Opportunity	Adequate designation width has been applied to accommodate risks and opportunities. Any variation can be accommodated within the proposed designation.	Additional detailed site investigations of mechanisms and extents of specific landslides.
Extent of alluvium in Hungry Creek area poorly understood	More extensive foundations for retaining structures, MSE walls. Ground treatment.	High Risk or High Opportunity	Conservative estimate of undercuts.	Additional site investigations.

15. Conclusions and recommendations

15.1 Conclusions

This report provides an assessment of the geotechnical design elements and ground engineering requirements with respect to the applications for resource consent and Notices of Requirement for the Project. It informs the assessments of effects from the construction and operation of the Project. It is based on preliminary assessments of the ground conditions and experience from the design, construction and operation of other major road projects in similar terrain in New Zealand including those within the Auckland Region.

The geotechnical engineering elements that have potential effects on the environment are associated with:

- Cut slopes – slope stability, rock fall hazards and erosion;
- Fill embankments – slope stability, embankment settlement, ground treatment/improvement;
- Landslides – slope stability and ground settlement;
- Earthworks – excavatability, re-use for construction and disposal of unsuitable or surplus materials; and
- Groundwater – settlement associated with earthworks, effect on slope stability.

These potential effects are considered by others in the Project Team and summarised in the Project's Assessment of Environmental Effects.

The management of these geotechnical elements for the Project has been demonstrated by the effective design and geotechnical engineering of major infrastructure projects in similar terrain and environments. The precedent and experience of other such schemes provides a reliable assessment of the main geotechnical risks and opportunities facing this Project.

An engineering geological model of the indicative alignment is presented in this report, which forms the basis of the assessment. The engineering geological model has been used to:

- Inform the preliminary geotechnical analyses;
- Refine and improve the indicative alignment and design elements; and
- Communicate the anticipated ground conditions for the Assessments of Environmental Effects.

There is potential variability in the ground conditions and ground model and the geotechnical assessments and designs have given consideration to the implications or impacts of these variations. Consequently, the models and detailed designs will need to be reviewed and developed further as the knowledge and understanding of the ground conditions and its impact on the Project evolves.

The indicative alignment shown on the Project drawings has been developed through a series of multi-disciplinary specialist studies and refinement. The geotechnical investigations and assessments have formed an integral part of the development of the indicative alignment and design elements.

The proposed designation will provide an adequate width and working area to accommodate the most likely range of variability of ground conditions expected to be encountered.

15.2 Recommendations

This Geotechnical Engineering Appraisal Report has also identified the main uncertainties, risks and opportunities remaining for the Project. To address these further, it is recommended that detailed investigations, assessments and designs of the various geotechnical elements outlined above are carried out prior to and during construction, as is required for all schemes of this nature.

Systematic and detailed investigations are recommended to enable site-specific solutions to be developed for all the main design elements. This recommendation includes further investigations of:

- Cut slopes – characterise weathering profiles, rock and soil conditions and strengths, dominant defects, shear zones, defect shear strengths, monitor groundwater conditions;
- Embankment foundations – foundation rock and soil conditions, strength, compressibility, dominant defects and shear strengths, monitor groundwater conditions;
- Landslides – determine mechanisms, rock and soil conditions, monitor activity, groundwater conditions;
- Earthworks properties – compaction, excavatability, suitability, strength and consolidation, durability, distribution;
- Spoil disposal locations – foundation conditions, groundwater conditions;
- Bridge and viaduct foundations – foundation conditions, rock strengths;
- Pavement subgrades – subgrade strength;
- Retaining wall locations – foundation conditions, soil/rock loads, groundwater conditions;
- Culverts – foundation conditions; and
- Groundwater conditions – characterise perched, percolating, artesian, permeability, fluctuations.

16. References

AS 4678-2002, Earth-Retaining Structures. Standards Australia.

AS 2159-2009 Piling – Design and installation. Standards Australia.

Ballance, P F and Williams, P W, 1992. The geomorphology of Auckland and Northland. In: J M Soons and M J Selby. Landforms of New Zealand. 2nd edition, 1992, pp. 127-136.

Ballance, P F and Gregory, M R, 1991. Parnell Grits – large subaqueous volcaniclastic gravity flows with multiple particle support mechanism. In: Fisher RV and Smith GA. Sedimentation in volcanic settings. S.l : Society for Sedimentary Geology, 1991, pp. 127-136.

Builders Regulations 1992 (SR 1992/150)

Chmoulian, A. Y. 2004. Briefing: Analysis of piled stabilisation of landslides. Geotechnical Engineering 157, April 2004, pp55-56. Proceedings of the Institution of Civil Engineers.

East, G.R.W. 1974. Inclined Plane Slope Failures in the Auckland Waitemata Soils; Three Case Histories with Different Remedial Measures. pp 5.17-5.24 in Proc. Symposium on Stability of Slopes in Natural Ground, New Zealand Institution of Engineers, Wellington.

Edbrooke, S W, et al, 2013. Geological Map of Manukau City, 1:50,000. s.l. : Institute of Geological & Nuclear Sciences, Unpublished geological map (http://maps.gns.cri.nz/website/citymap/).
Edbrooke, S.W, 2001. Geology of the Auckland Area. 1:250,000 scale geological map and memoir. Institute of Geology and Nuclear Science, 2001.

Further North Alliance, 2013. Pūhoi to Warkworth Stage 2 – Geotechnical Factual Report. Further North Alliance, May 2013.

GNS, 2013. Two quakes for Auckland. Retrieved from info.geonet.org.nz/display/quake/2013/03/17/two+quakes+for+Auckland.

GNS, 2007. Hauraki Gulf earthquake shakes up Aucklanders – 22/02/2007. Retrieved from www.gns.cri.nz/home/news-and-events/media-releases/hauraki-gulf-quake.

Isaac. M J, Herzer, R.H, Brook, F.J, Hayward, B.W, 1994. Cretaceous and Cenozoic sedimentary basins of Northland, New Zealand. Institute of Geological and Nuclear Silences, 1994.

Moon V G and Healy T, 1994. Mechanisms of Coastal Cliff Retreat and Hazard Zone Delineation in Soft Flysch Deposits. Journal of Coastal Research, Vol. 10, No. 3, pp. 663-680.

National Center for Earthquake Engineering Research (NCEER). 1997. Proceedings of the NCEER Workshop on Evaluation of Liquefaction Resistance of Soils, T.L. Youd & I.M. Idriss, Editors, Technical Report NCEER-97-022.

Northern Gateway Alliance, 2008a. SH1: Northern Motorway Extension (ALPURT B2), Factual Report Ground Investigation Volume Three: Laboratory Testing. Northern Gateway Alliance, October 2008. NGA-RP-G-113-Rev. H.

Northern Gateway Alliance, 2008b. SH1: Northern Motorway Extension (ALPURT B2), Geotechnical Report Chin Hill Rock Fall. Northern Gateway Alliance, October 2008. NGA-RP-G-522

NZGI, 2010. New Zealand Geopreservation Inventory. [Cited: 13 04 2010]. http://homepages.ihug.co.nz/~bw.hayward/NZGI/

NZGS, 2005. Guidelines for the Field Classification and Description of Soil and Rock for Engineering Purposes. New Zealand Geotechnical Society, 2005.

NZ Transport Agency 2003. Bridge Manual Second Edition. New Zealand Transport Agency, June 2003.

Opus Consultants, 2002. PA1400 - SH1 RS 274 Schedewys Hill Realignment RP 274 /1.7-4.5 Geotechnical Preliminary Design Report, June 2002. Reference GS 02/15.

Pettifer, G & Fookes, P, 1994. A revision of the Graphical Method for Assessing the Excavatability of Rock, QJEG, Vol 27, pp 145-164

Rait, G J, 2000. Thrust transport directions in the Northland Allochthon, New Zealand. New Zealand Journal of Geology and Geophysics, Vol. 43, pp. 271-288.

Ritchie, A.M, 1963. The evaluation of rockfall and its control. Highway Record 17 pp 13-28.

SKM, 2010. Puhoi to Warkworth Preliminary Geological and Geotechnical Appraisal. Sinclair Knight Merz, September 2010

SKM, 2011. Puhoi to Walkworth - Preliminary Geotechnical Investigation Factual Report. Sinclair Knight Merz, September 2011, Report No. ZB01072-IR-025

Stirling, M.W., McVerry, G.H., Gerstenberger, M., Litchfield, N.J., Van Dissen, R., Berryman, K.R., Langridge, R.M., Nicol, A., Smith, W.D., Villamor, P., Wallace, L., Clark, K., Reyners, M., Barnes, P., Lamarche, G., Nodder, S., Pettinga, J., Bradley, B., Buxton, R., Rhoades, D., Jacobs, K. National Seismic Hazard Model for New Zealand: 2010 Update. Bulletin of the Seismological Society of America (submitted).

Stirling, M.W., McVerry, G.H., Gerstenberger, M. 2012. New National Seismic Hazard Model for New Zealand: Changes to Estimated Long-Term Hazard. Proceedings of 2012 NZSEE Conference, New Zealand Society for Earthquake Engineering.

Tonkin and Taylor, 2004. Snells Beach to Algies Bay Slope Stability Review, Preliminary Assessment Report. Tonkin and Taylor Ltd, 2004. Reference number 20610.

Tūhono Consortium, 2011. Hydrogeological Assessment Report for the Waterview Connection Tunnels and Great North Road Interchange. Report prepared for the NZTA under Contract NZTA CA3466.

Victorian Government Department of Sustainability and Environment. 2010. Victorian Best Practice Guidelines for Assessing and Managing Coastal Acid Sulfate Soils, Page 15.

Williams, A L, 1996. Slope instability Hazards in the Auckland Region, A Preliminary Assessment. Auckland Regional Council. Technical Publication No. 71. ISSN 1172 6415.

Williams, A.L., Toan, D.V., and Prebble, W.M. 2004. Engineering Properties of Clay Seams within the Waitemata Group Rocks of Auckland. 9th Australia New Zealand Conference on Geomechanics, Auckland – February 2004, Proceedings, Vol 9 pp 840-845.

Viggiani, C. 1981. Ultimate lateral load on piles used to stabilise landslides. Proceedings of 10th International Conference on Soil Mechanics and Foundation Engineering, Stockholm, 1981, vol. 3, pp555-560.

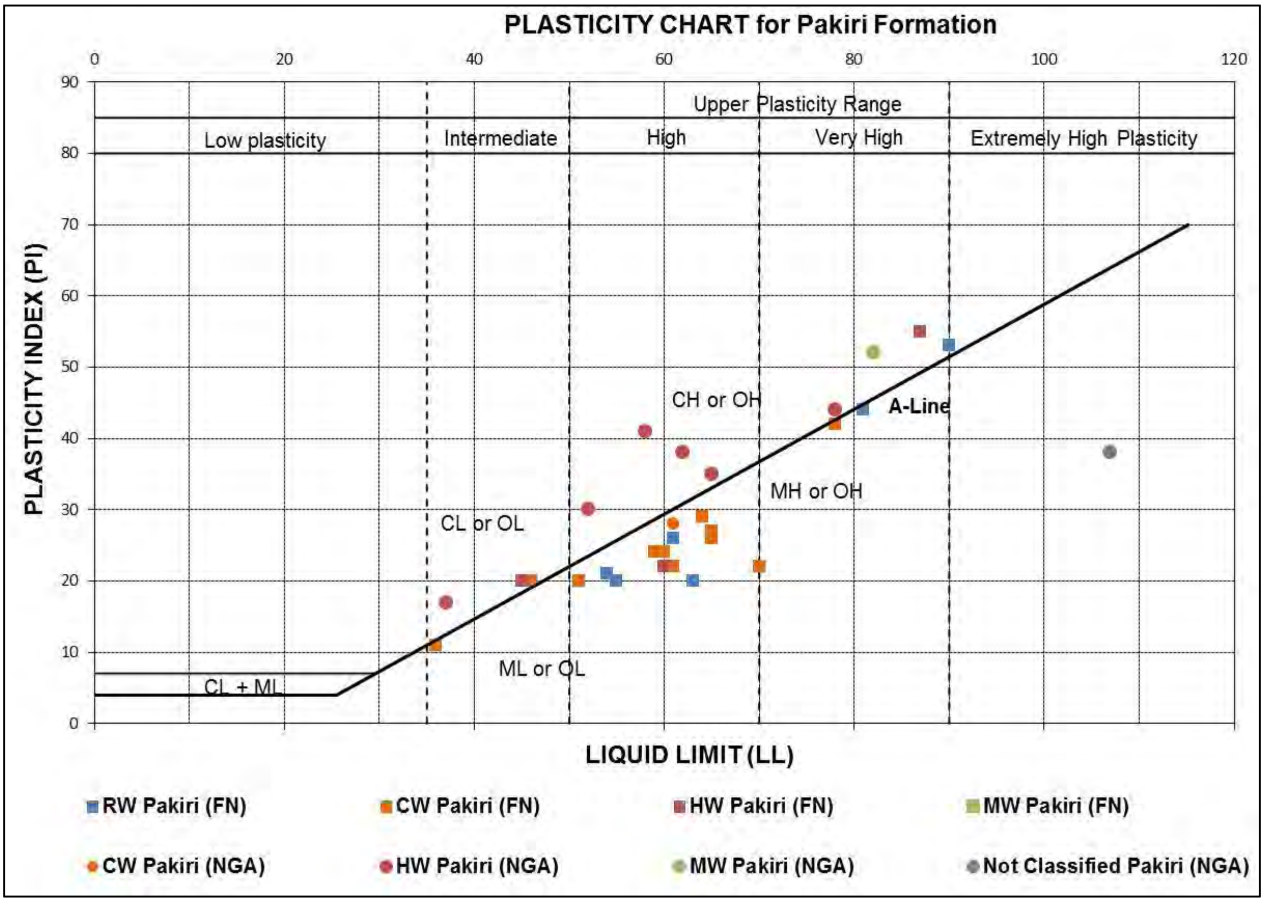
Williams, H.A. 2003: Geophysical and structural investigation of basement greywacke in the Auckland region, University of Auckland. Unpublished MSc thesis, lodged in the Library, University of Auckland.

Winkler, G.E, 2003. Geotechnical Engineering of the Northland Allochthon. Proceedings of the "Geotechnics on the Volcanic Edge" symposium.

Wood J.H., and Elms D.G. 1990. Seismic design of bridge abutments and retaining walls, RRU Bulletin 84, Vol. 2, Transit New Zealand.

Wylie, D C, Mah, C W, 2004. *Rock Slope Engineering* (4th Edition). USA and Canada: Spon Press

Appendix A. Summary Graphs of Plasticity and UCS Tests



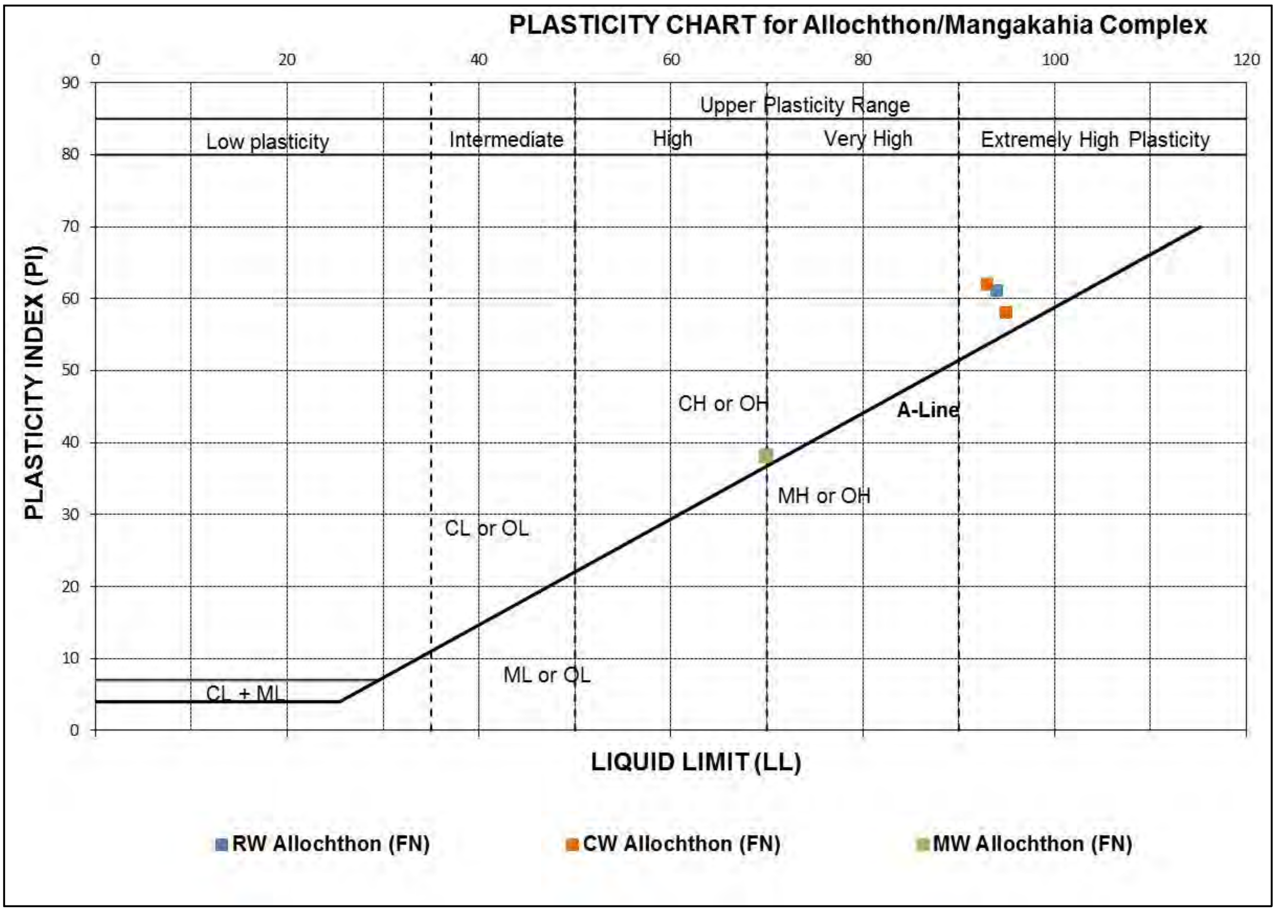
Notes: NGA = Northern Gateway Alliance data for detailed design of NGTR.

FN = Further North Alliance Stage 1 and Stage 2 investigation data for Pūhoi to Warkworth Project.

RW = Residually weathered Pakiri Formation.

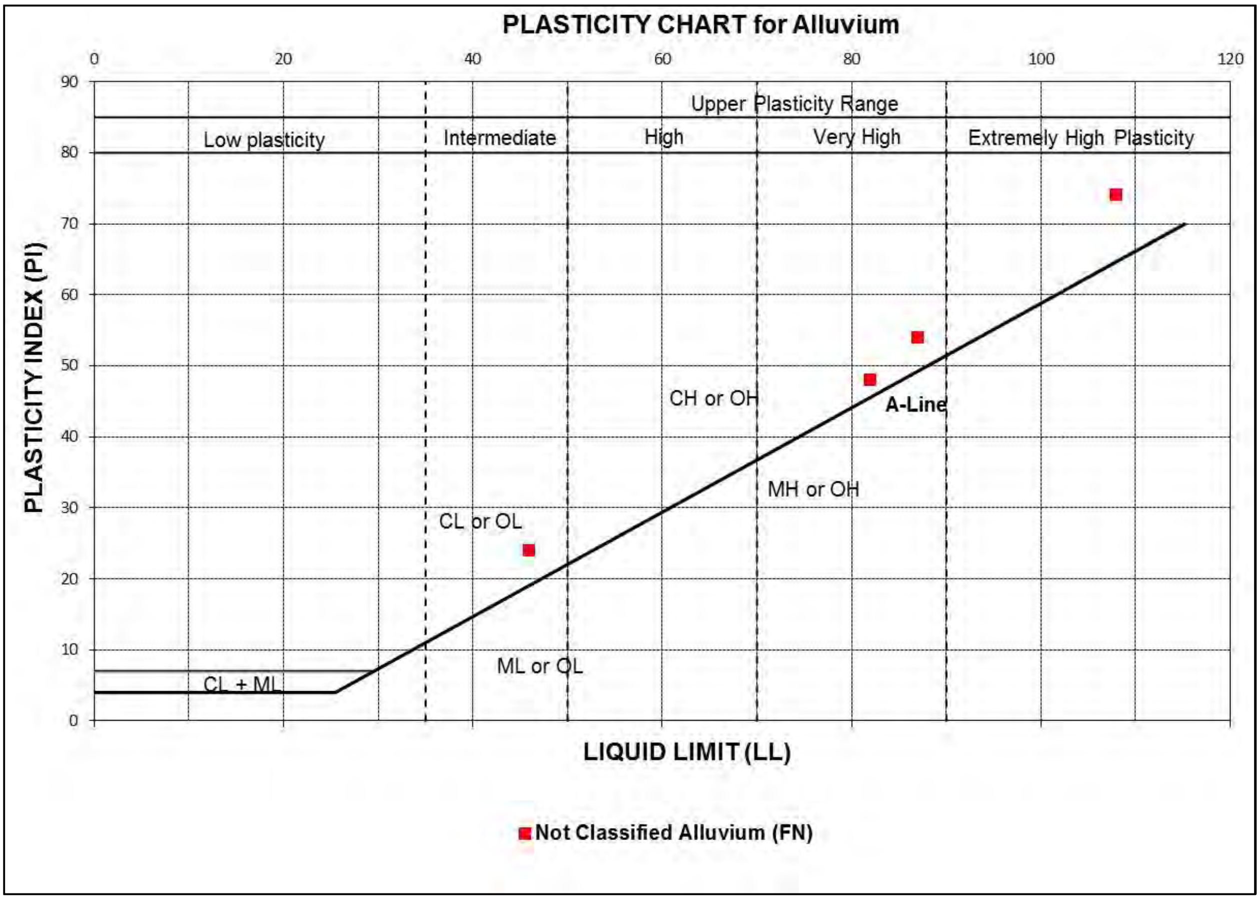
CW = Completely weathered Pakiri Formation.

Figure 21: Plasticity chart for Pakiri Formation soil samples



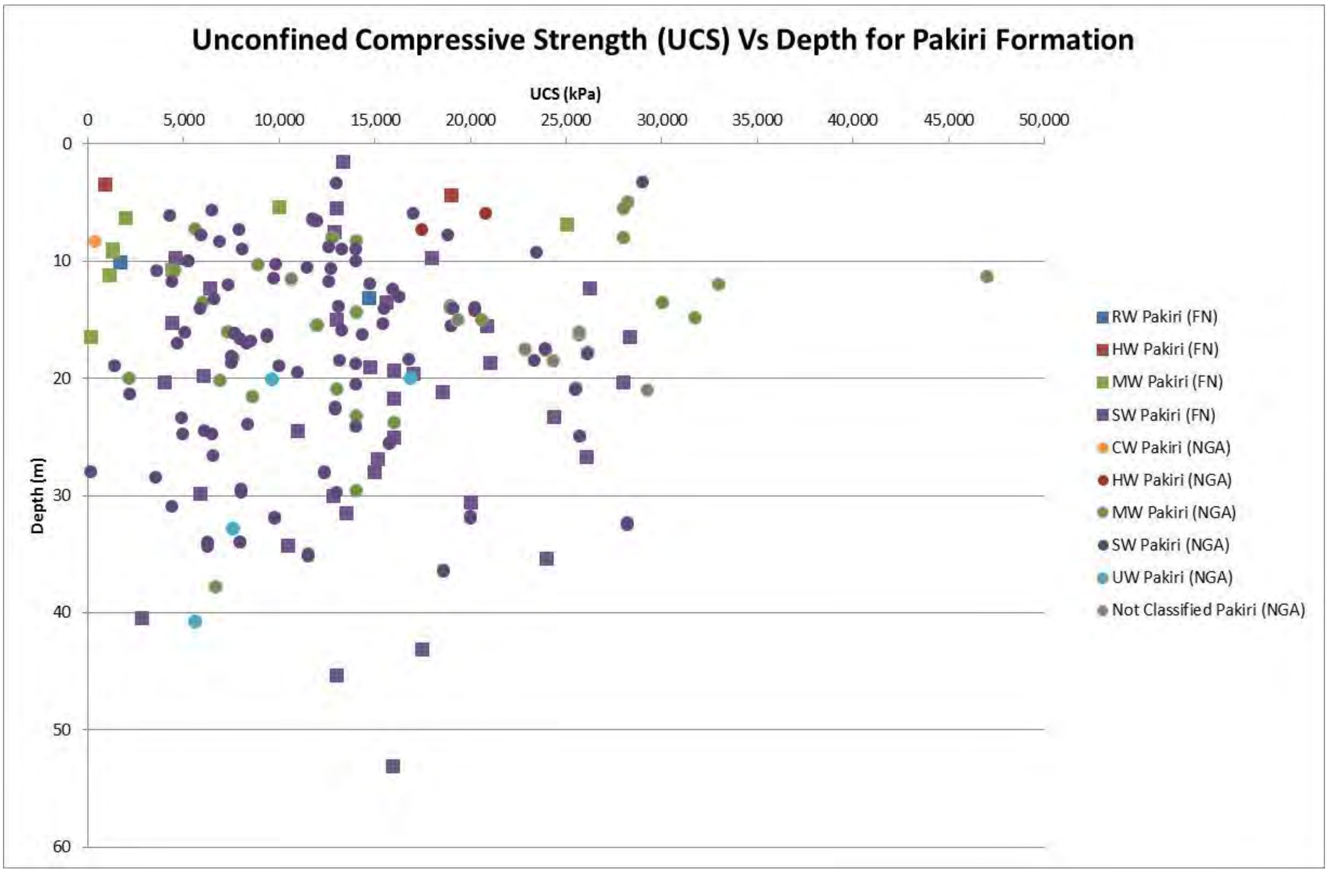
Notes: FN = Further North Alliance Stage 1 and Stage 2 investigation data for Pūhoi to Warkworth Project.
RW = Residually weathered Northland Allochthon.
CW = Completely weathered Northland Allocthon.
MW = Moderately weathered Northland Allocthon.

Figure 22: Plasticity chart for Northland Allochthon soil samples.



Notes: FN = Further North Alliance Stage 1 and Stage 2 investigation data for Pūhoi to Warkworth Project.

Figure 23: Plasticity chart for Alluvium soil samples.



Notes: NGA = Northern Gateway Alliance data for detailed design of NGTR.

FN = Further North Alliance Stage 1 and Stage 2 investigation data for Pūhoi to Warkworth Project.

HW = Highly weathered Pakiri Formation
(often difficult to obtain samples for UCS testing due to its weathered nature)

MW = Moderately weathered Pakiri Formation
(can be difficult to obtain samples for UCS testing due to its weathered nature)

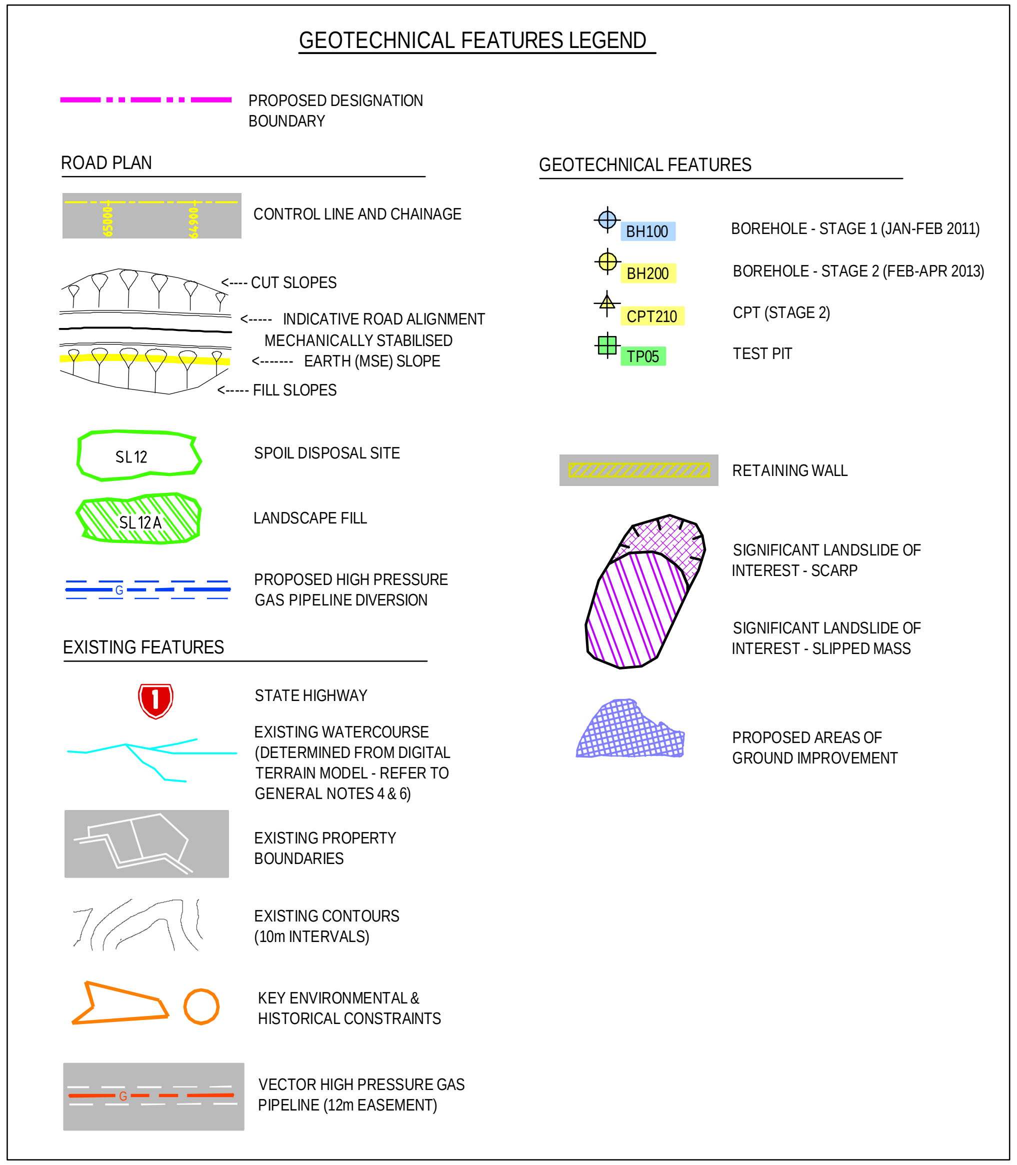
SW = Slightly weathered Pakiri Formation

UW = Unweathered Pakiri Formation

Figure 24: Test Results for Unconfined Compressive Strength of Pakiri Formation.

Appendix B. Geotechnical Features Drawings

GT-002	Geotechnical Features - Notes and Legend
GT-200	Geotechnical Features - Sheet Layout
GT-201	Geotechnical Features - Sheet 1 of 15
GT-202	Geotechnical Features - Sheet 2 of 15
GT-203	Geotechnical Features - Sheet 3 of 15
GT-204	Geotechnical Features - Sheet 4 of 15
GT-205	Geotechnical Features - Sheet 5 of 15
GT-206	Geotechnical Features - Sheet 6 of 15
GT-207	Geotechnical Features - Sheet 7 of 15
GT-208	Geotechnical Features - Sheet 8 of 15
GT-209	Geotechnical Features - Sheet 9 of 15
GT-210	Geotechnical Features - Sheet 10 of 15
GT-211	Geotechnical Features - Sheet 11 of 15
GT-212	Geotechnical Features - Sheet 12 of 15
GT-213	Geotechnical Features - Sheet 13 of 15
GT-214	Geotechnical Features - Sheet 14 of 15
GT-215	Geotechnical Features - Sheet 15 of 15



GENERAL NOTES

1. ALL MEASUREMENTS ARE IN METRES UNLESS OTHERWISE STATED.
2. ALL NAMED ROADS SHALL BE ASSUMED TO BE PUBLIC UNLESS STATED OTHERWISE.
3. AERIAL IMAGE FROM AUCKLAND COUNCIL AERIAL SURVEY, 2012.
4. DIGITAL TERRAIN MODEL DERIVED FROM AERIAL PHOTOGRAMETRIC SURVEY (MARCH 2010) TO NZTM PROJECTION.
5. EXISTING PROPERTY BOUNDARIES SOURCED FROM LINZ, APRIL 2013 UPDATE.
6. DOES NOT DIFFERENTIATE BETWEEN INTERMITTENT AND PERMANENT STREAMS, REFER TO DRAWING FE-101.
7. FOR DETAILS OF OPERATIONAL WATER MANAGEMENT, REFER TO DRAWINGS SW-001 AND SW-100 TO SW-115.
8. FOR STRUCTURES PLANS, REFER TO DRAWINGS S-001 TO S-111.

GEOTECHNICAL NOTES

1. THE GEOTECHNICAL FEATURES DRAWINGS GT-201 TO GT-215 ARE NOT INTENDED TO BE A COMPREHENSIVE RECORD OF ALL GEOTECHNICAL FEATURES. ONLY KEY OR SIGNIFICANT GEOTECHNICAL FEATURES THAT ARE OF SPECIFIC INTEREST AND RELEVANT TO THE INDICATIVE ROAD ALIGNMENT ARE SHOWN ON THE GEOTECHNICAL FEATURES DRAWINGS.
2. FOR LOCATIONS OF ALL IDENTIFIED LANDSLIDE FEATURES, REFER TO DRAWINGS GT-100 TO GT-117.

AMD	DATE	DESIGN REVIEW	REVD D. MGR	APPD A. MGR	PURPOSE OF ISSUE / AMENDMENT
0	30/08/13	DJW	MRH	TI	ISSUE FOR NOR / CONSENT

FURTHER NORTH

DISCLAIMER
The information shown on this drawing is solely for the purposes of supporting RMA applications for statutory approvals. All information shown is subject to review for compliance with approved consents and the outcomes of final design.

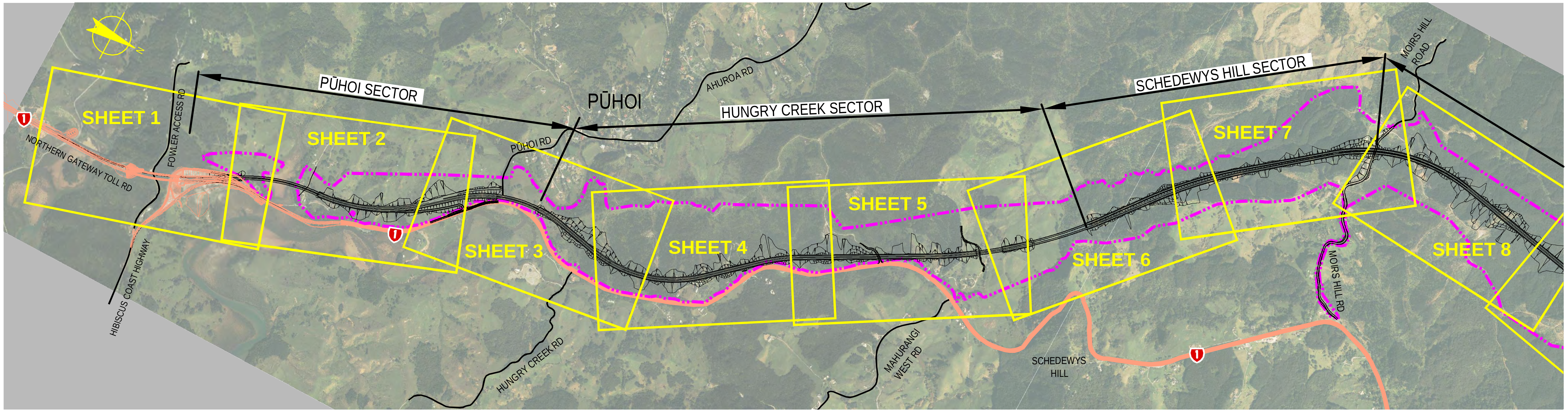
ARA TŪHONO - PŪHOI TO WELLSFORD
PŪHOI TO WARKWORTH - FOR RMA APPROVALS

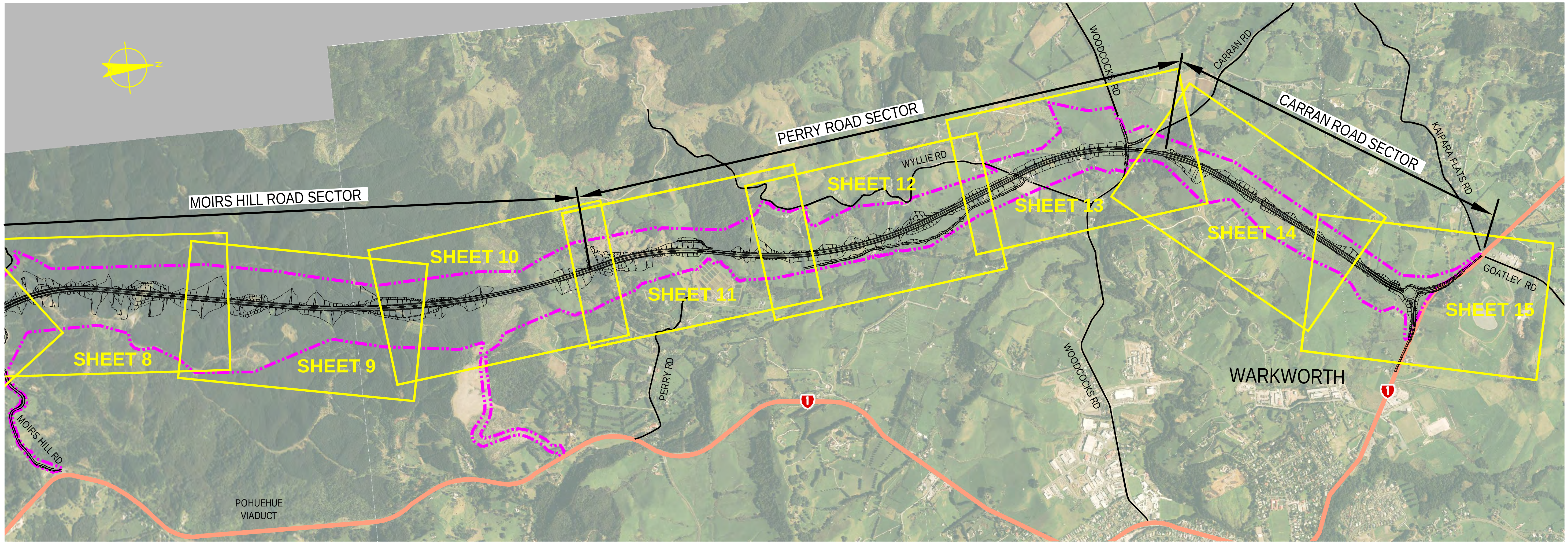
DRAWN	DRAFTING CHECK	REVIEWED DISCIPLINE MANAGER	APPROVED ALLIANCE MANAGER
SNP	OJH	MRH	TI
DESIGNED OJH	DESIGN REVIEW DJW		

GEOTECHNICAL FEATURES NOTES AND LEGEND

SCALE	CONTRACT No	DRAWING No	AMDT
NOT TO SCALE	PA3748	GT-002	0

S:\Further North - PAA\300 Design\300.5 Technical\01-Drawing Production\CADD\Drawings\GT-002.dwg Plot Date: 31 October, 2013 - 8:42 AM





AMD	DATE	DESIGN REVIEW	REV'D D. MGR	APP'D A. MGR	PURPOSE OF ISSUE / AMENDMENT
0	30/08/13	DJW	MRH	TI	ISSUE FOR NOR / CONSENT

FURTHER NORTH

DISCLAIMER
The information shown on this drawing is solely for the purposes of supporting RMA applications for statutory approvals.
All information shown is subject to review for compliance with approved consents and the outcomes of final design.

ARA TŪHONO - PŪHOI TO WELLSFORD

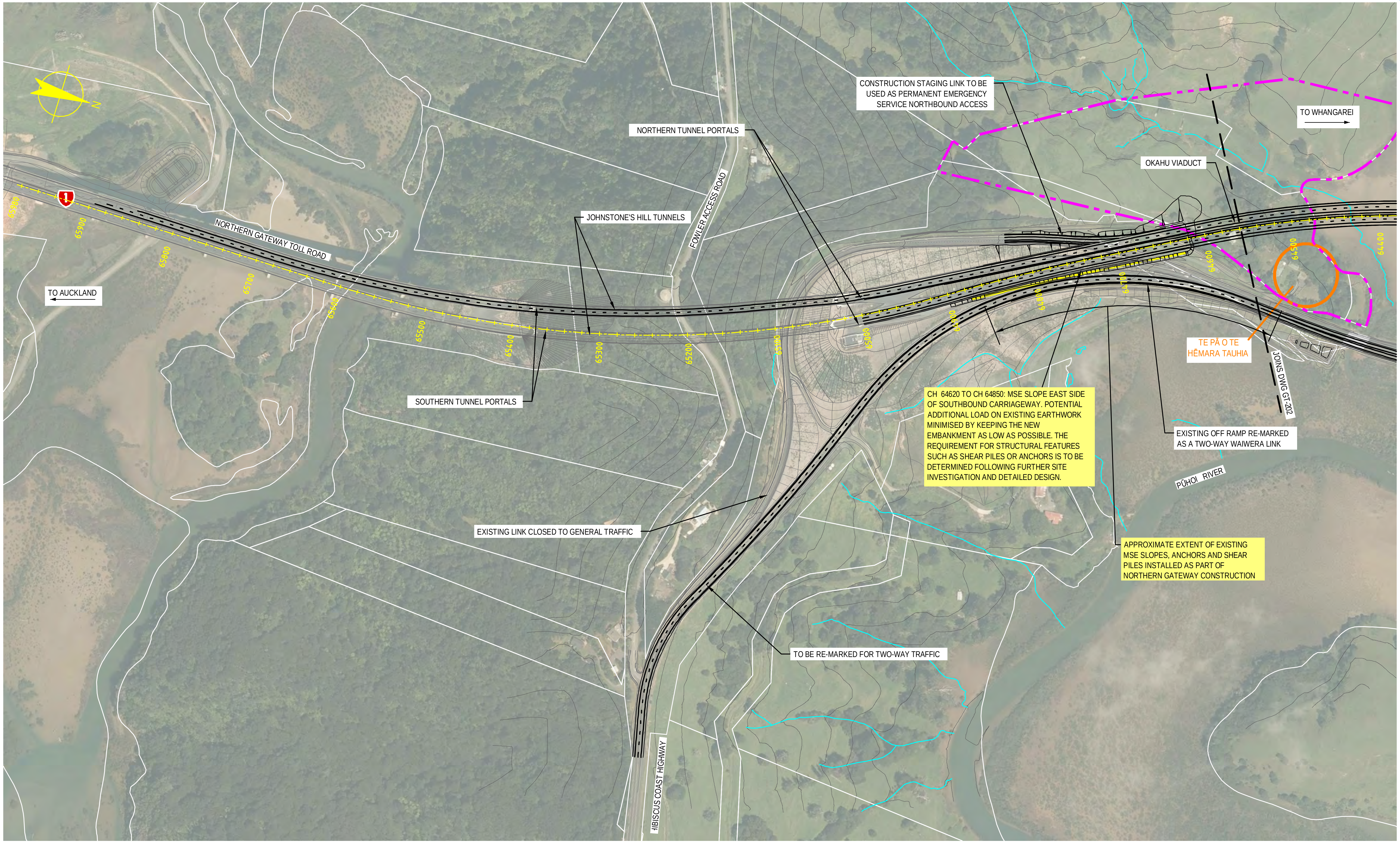
PŪHOI TO WARKWORTH - FOR RMA APPROVALS

DRAWN	DRAFTING CHECK	REVIEWED DISCIPLINE MANAGER	APPROVED ALLIANCE MANAGER
SNP	OJH	MRH	TI
DESIGNED: OJH	DESIGN REVIEW: DJW		

GEOTECHNICAL FEATURES SHEET LAYOUT

SCALE	CONTRACT No	DRAWING No	AMDT
NOT TO SCALE	PA3748	GT-200	0

S:\Further North - PAA\300 Design\300.5 Technical\01-Drawing Production\CADD\Drawings\GT-200.dwg Plot Date: 26 August , 2013 - 11:09 AM



NOTE: FOR GENERAL NOTES AND LEGEND, REFER TO DRAWING GT-002

0 20 40 60 80 100m
SCALE 1:4,000 @ A3 SIZE

AMD	DATE	DESIGN REVIEW	REVD D. MGR	APPD A. MGR	PURPOSE OF ISSUE / AMENDMENT
0	30/08/13	DJW	MRH	TI	ISSUE FOR NOR / CONSENT

FURTHER NORTH

DISCLAIMER
The information shown on this drawing is solely for the purposes of supporting RMA applications for statutory approvals.
All information shown is subject to review for compliance with approved consents and the outcomes of final design.

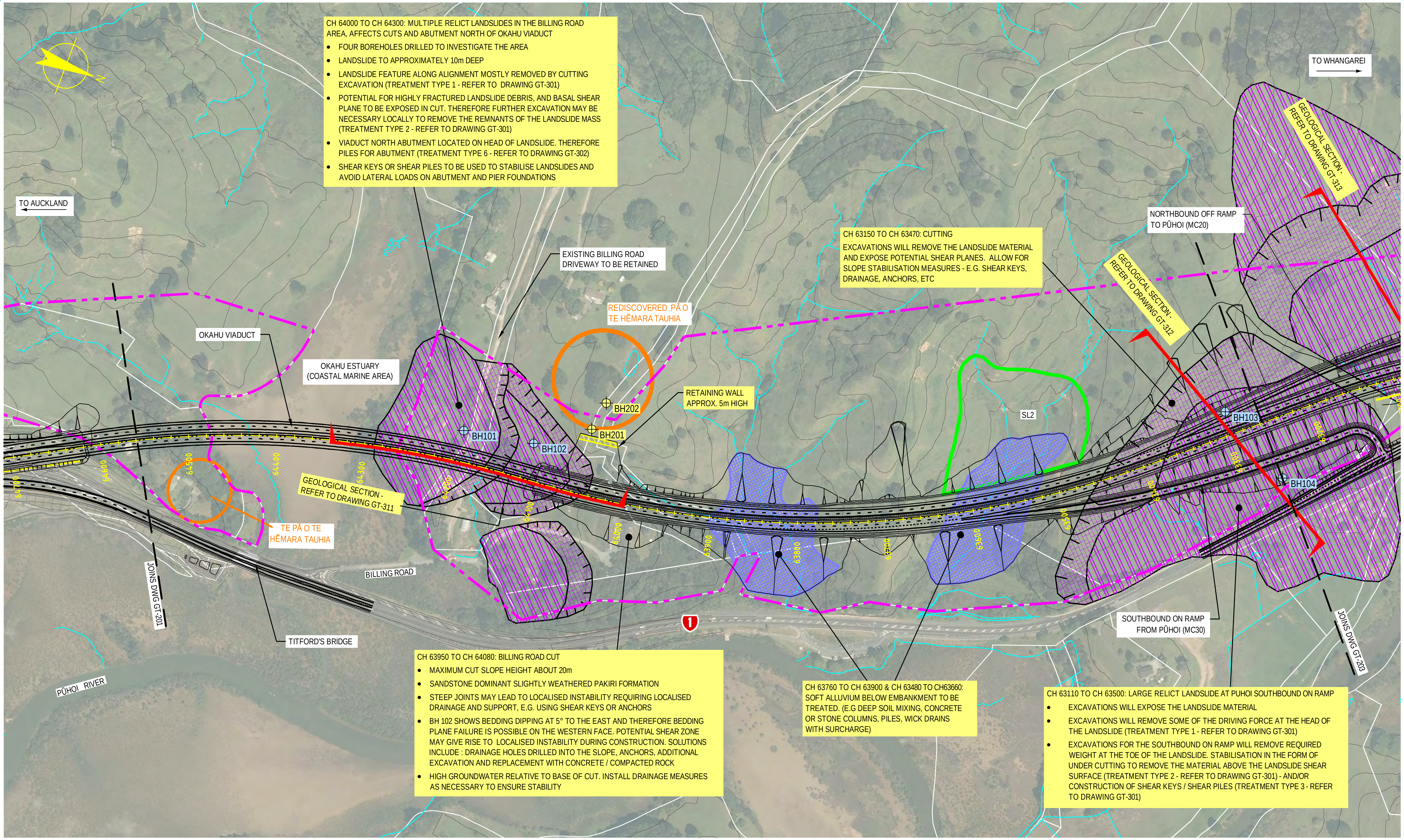
ARA TŪHONO - PŪHOI TO WELLSFORD
PŪHOI TO WARKWORTH - FOR RMA APPROVALS

DRAWN	DRAFTING CHECK	REVIEWED DISCIPLINE MANAGER	APPROVED ALLIANCE MANAGER
SNP	OJH	MRH	TI
DESIGNED OJH	DESIGN REVIEW DJW		

GEOTECHNICAL FEATURES
SHEET 1 OF 15

SCALE	CONTRACT No	DRAWING No	AMDT
AS SHOWN	PA3748	GT-201	0

S:\Further North - PAA\300 Design\300.5 Technical\01-Drawing Production\CADD\Drawings\GT-201_GT-205.dwg Plot Date: 01 November , 2013 - 8:37 AM



NOTE: FOR GENERAL NOTES AND LEGEND, REFER TO DRAWING GT-002

0 20 40 60 80 100m
SCALE 1:4,000 @ A3 SIZE

AMD	DATE	DESIGN REVIEW	REV'D D. MGR	APP'D A. MGR	PURPOSE OF ISSUE / AMENDMENT
0	30/08/13	DJW	MRH	TI	ISSUE FOR NOR / CONSENT

FURTHER NORTH

DISCLAIMER
The information shown on this drawing is solely for the purposes of supporting RMA applications for statutory approvals.
All information shown is subject to review for compliance with approved consents and the outcomes of final design.

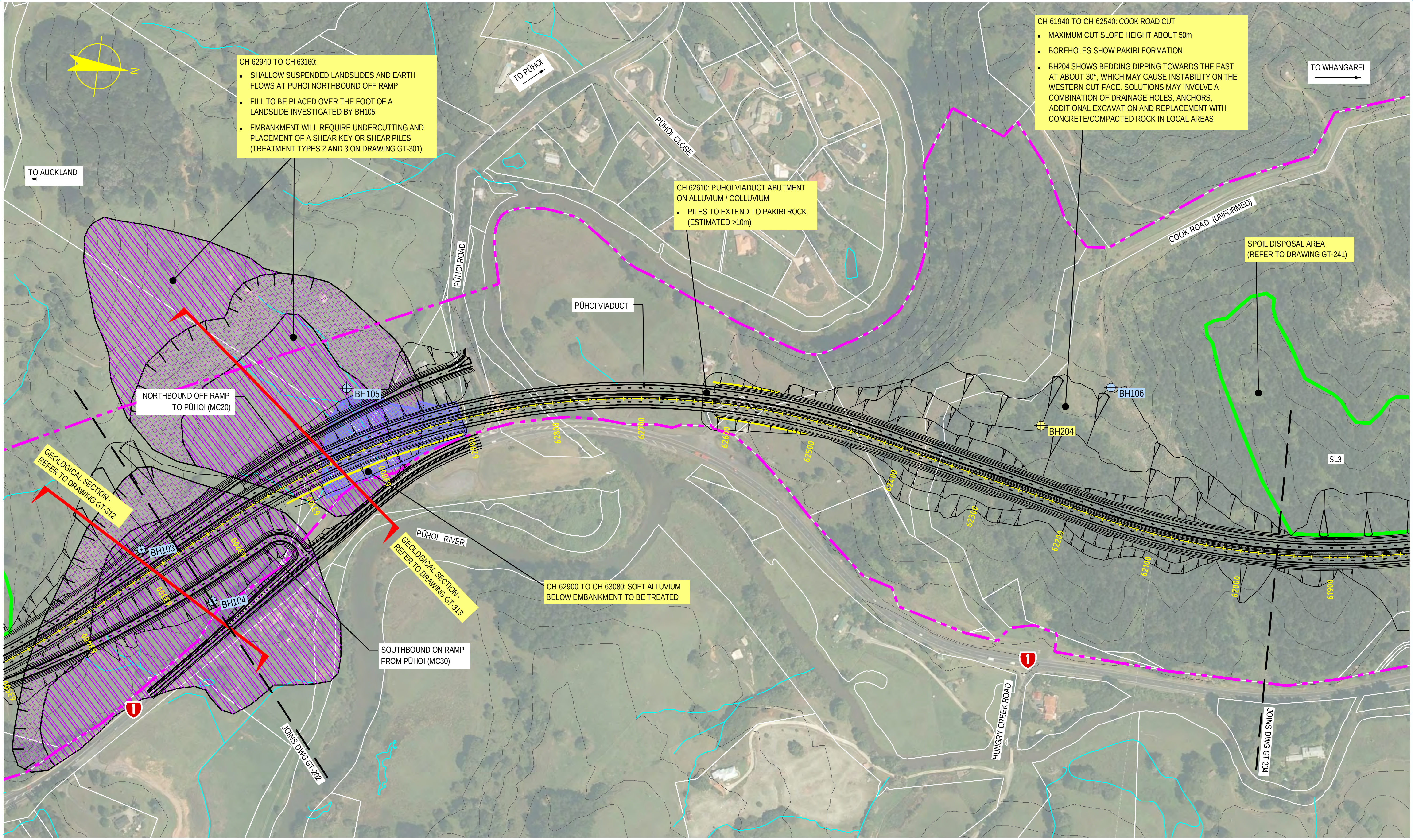
ARA TŪHONO - PŪHOI TO WELLSFORD
PŪHOI TO WARKWORTH - FOR RMA APPROVALS

DRAWN	DRAFTING CHECK	REVIEWED DISCIPLINE MANAGER	APPROVED ALLIANCE MANAGER
SNP	OJH	MRH	TI
DESIGNED: OJH	DESIGN REVIEW: DJW		

GEOTECHNICAL FEATURES
SHEET 2 OF 15

SCALE	CONTRACT No	DRAWING No	AMDT
AS SHOWN	PA3748	GT-202	0

S:\Further North - PAA\300 Design\300.5 Technical\01-Drawing Production\CADD\Drawings\GT-201_GT-205.dwg Plot Date: 01 November , 2013 - 8:39 AM



NOTE: FOR GENERAL NOTES AND LEGEND, REFER TO DRAWING GT-002

0 20 40 60 80 100m
SCALE 1:4,000 @ A3 SIZE

AMD	DATE	DESIGN REVIEW	REVD D. MGR	APPD A. MGR	PURPOSE OF ISSUE / AMENDMENT
0	30/08/13	DJW	MRH	TI	ISSUE FOR NOR / CONSENT

FURTHER NORTH

DISCLAIMER
The information shown on this drawing is solely for the purposes of supporting RMA applications for statutory approvals.
All information shown is subject to review for compliance with approved consents and the outcomes of final design.

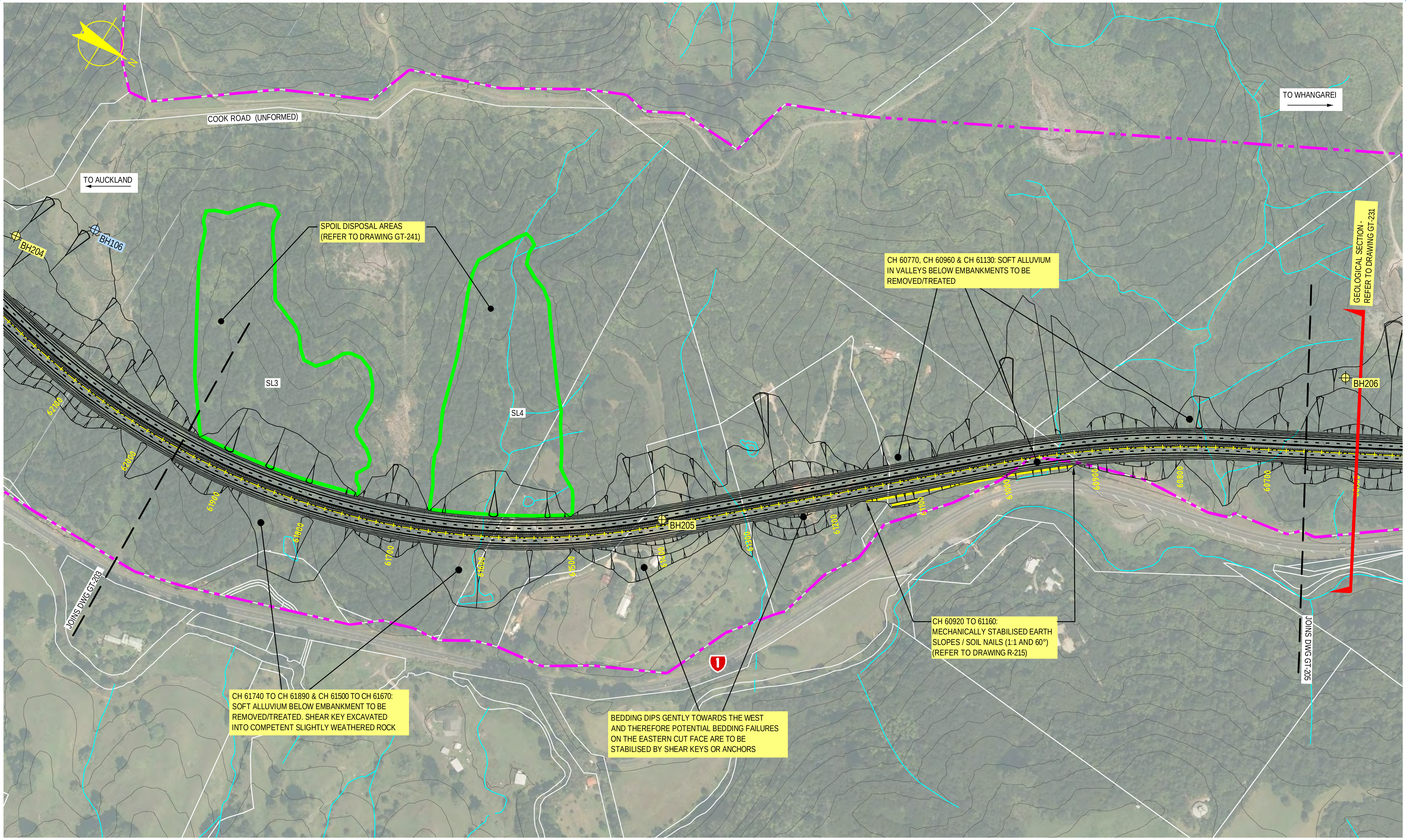
ARA TŪHONO - PŪHOI TO WELLSFORD
PŪHOI TO WARKWORTH - FOR RMA APPROVALS

DRAWN	DRAFTING CHECK	REVIEWED DISCIPLINE MANAGER	APPROVED ALLIANCE MANAGER
SNP	OJH	MRH	TI
DESIGNED OJH	DESIGN REVIEW DJW		

GEOTECHNICAL FEATURES
SHEET 3 OF 15

SCALE	CONTRACT No	DRAWING No	AMDT
AS SHOWN	PA3748	GT-203	0

S:\Further North - PAA\300 Design\300.5 Technical\01-Drawing Production\CADD\Drawings\GT-201_GT-205.dwg   Plot Date: 01 November, 2013 - 8:44 AM



NOTE: FOR GENERAL NOTES AND LEGEND, REFER TO DRAWING GT-002

0 20 40 60 80 100m
SCALE 1:4,000 @ A3 SIZE

AMD	DATE	DESIGN REVIEW	REV'D D. MGR	APP'D A. MGR	PURPOSE OF ISSUE / AMENDMENT
0	30/08/13	DJW	MRH	TI	ISSUE FOR NOR / CONSENT

FURTHER NORTH

DISCLAIMER
The information shown on this drawing is solely for the purposes of supporting RMA applications for statutory approvals.
All information shown is subject to review for compliance with approved consents and the outcomes of final design.

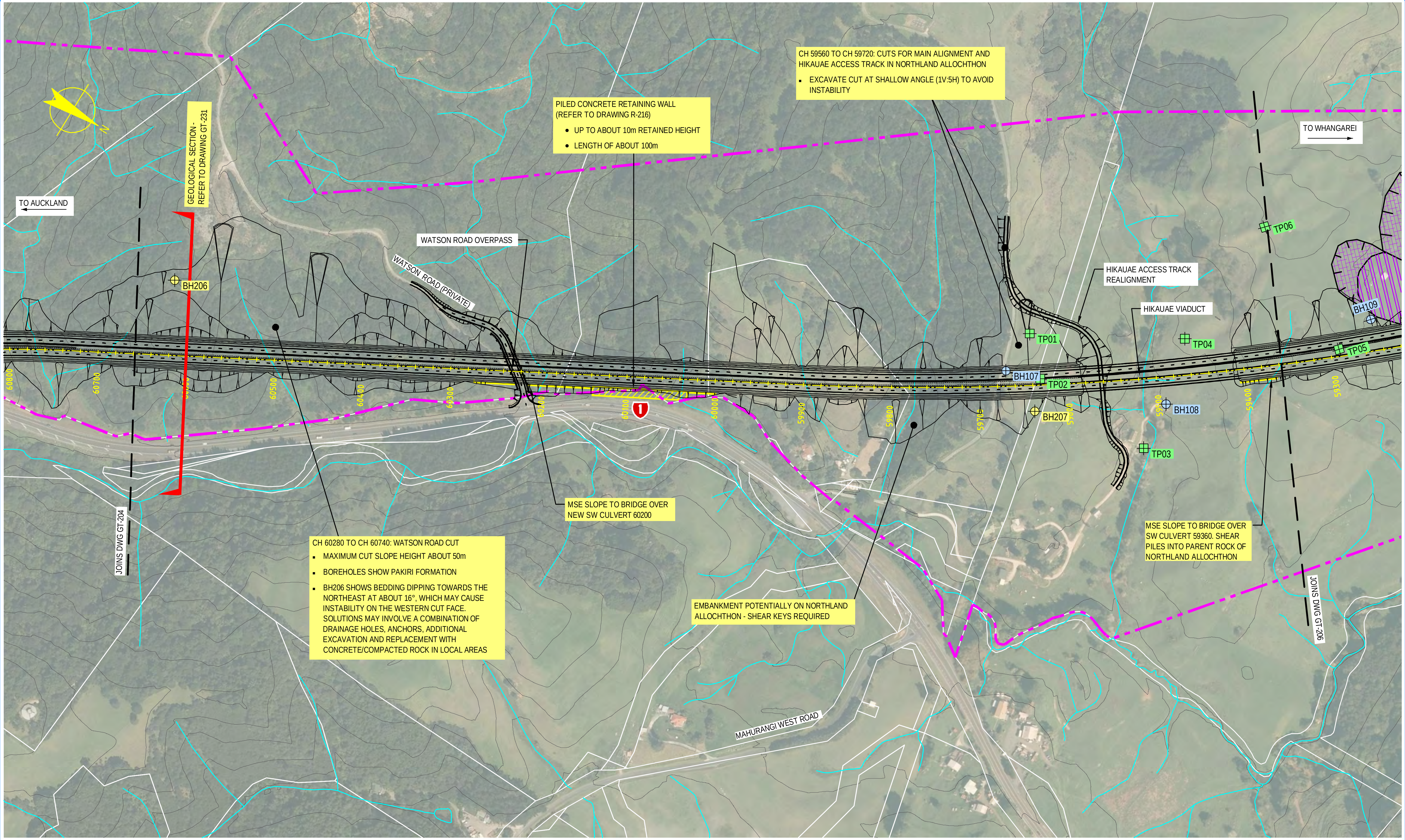
ARA TŪHONO - PŪHOI TO WELLSFORD
PŪHOI TO WARKWORTH - FOR RMA APPROVALS

DRAWN	DRAFTING CHECK	REVIEWED DISCIPLINE MANAGER	APPROVED ALLIANCE MANAGER
SNP	OJH	MRH	TI
DESIGNED: OJH	DESIGN REVIEW: DJW		

GEOTECHNICAL FEATURES
SHEET 4 OF 15

SCALE	CONTRACT No	DRAWING No	AMDT
AS SHOWN	PA3748	GT-204	0

S:\Further North - PAA\300 Design\300.5 Technical\01-Drawing Production\CADD\Drawings\GT-201_GT-205.dwg Plot Date: 01 November , 2013 - 8:45 AM



NOTE: FOR GENERAL NOTES AND LEGEND, REFER TO DRAWING GT-002

0 20 40 60 80 100m
SCALE 1:4,000 @ A3 SIZE

AMD	DATE	DESIGN REVIEW	REV'D D. MGR	APP'D A. MGR	PURPOSE OF ISSUE / AMENDMENT
0	30/08/13	DJW	MRH	TI	ISSUE FOR NOR / CONSENT

FURTHER NORTH

DISCLAIMER
The information shown on this drawing is solely for the purposes of supporting RMA applications for statutory approvals.
All information shown is subject to review for compliance with approved consents and the outcomes of final design.

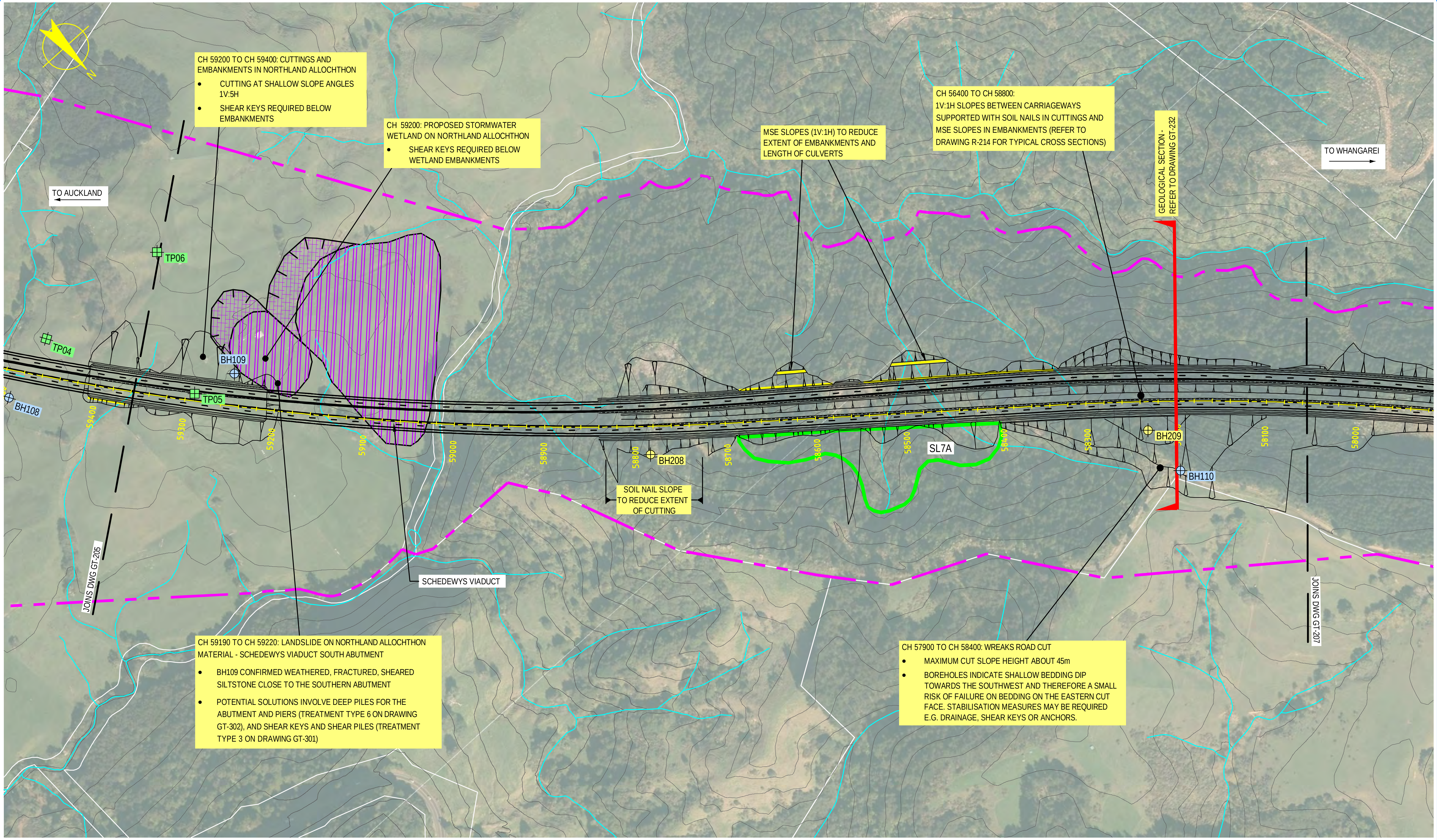
ARA TŪHONO - PŪHOI TO WELLSFORD
PŪHOI TO WARKWORTH - FOR RMA APPROVALS

DRAWN	DRAFTING CHECK	REVIEWED DISCIPLINE MANAGER	APPROVED ALLIANCE MANAGER
SNP	OJH	MRH	TI
DESIGNED OJH	DESIGN REVIEW DJW		

GEOTECHNICAL FEATURES
SHEET 5 OF 15

SCALE	CONTRACT No.	DRAWING No.	AMDT
AS SHOWN	PA3748	GT-205	0

S:\Further North - PAA\300 Design\300.5 Technical\01-Drawing Production\CADD\Drawings\GT-201_GT-205.dwg Plot Date: 01 November , 2013 - 8:46 AM



NOTE: FOR GENERAL NOTES AND LEGEND, REFER TO DRAWING GT-002

0 20 40 60 80 100m
SCALE 1:4,000 @ A3 SIZE

AMD	DATE	DESIGN REVIEW	REVD D. MGR	APPD A. MGR	PURPOSE OF ISSUE / AMENDMENT
0	30/08/13	DJW	MRH	TI	ISSUE FOR NOR / CONSENT

FURTHER NORTH

DISCLAIMER
The information shown on this drawing is solely for the purposes of supporting RMA applications for statutory approvals.
All information shown is subject to review for compliance with approved consents and the outcomes of final design.

ARA TŪHONO - PŪHOI TO WELLSFORD

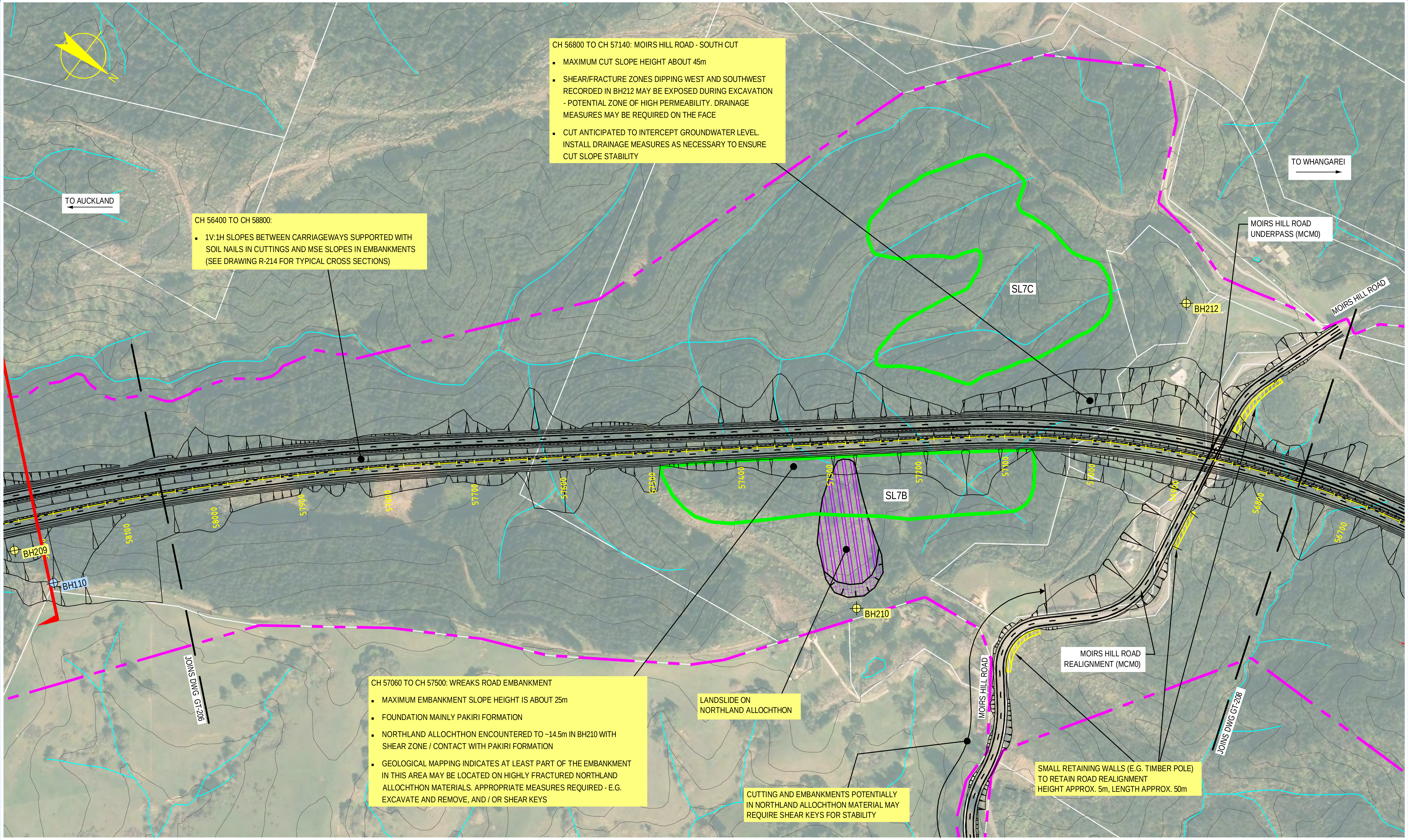
PŪHOI TO WARKWORTH - FOR RMA APPROVALS

DRAWN	DRAFTING CHECK	REVIEWED DISCIPLINE MANAGER	APPROVED ALLIANCE MANAGER
SNP	OJH	MRH	TI
DESIGNED OJH	DESIGN REVIEW DJW		

GEOTECHNICAL FEATURES
SHEET 6 OF 15

SCALE	CONTRACT No	DRAWING No	AMDT
AS SHOWN	PA3748	GT-206	0

S:\Further North - PAA\300 Design\300.5 Technical\01-Drawing Production\CADD\Drawings\GT-206_GT-210.dwg Plot Date: 01 November, 2013 - 8:58 AM



NOTE: FOR GENERAL NOTES AND LEGEND, REFER TO DRAWING GT-002

0 20 40 60 80 100m
SCALE 1:4,000 @ A3 SIZE

AMD	DATE	DESIGN REVIEW	REVD D. MGR	APP'D A. MGR	PURPOSE OF ISSUE / AMENDMENT
0	30/08/13	DJW	MRH	TI	ISSUE FOR NOR / CONSENT

FURTHER NORTH

DISCLAIMER
The information shown on this drawing is solely for the purposes of supporting RMA applications for statutory approvals. All information shown is subject to review for compliance with approved consents and the outcomes of final design.

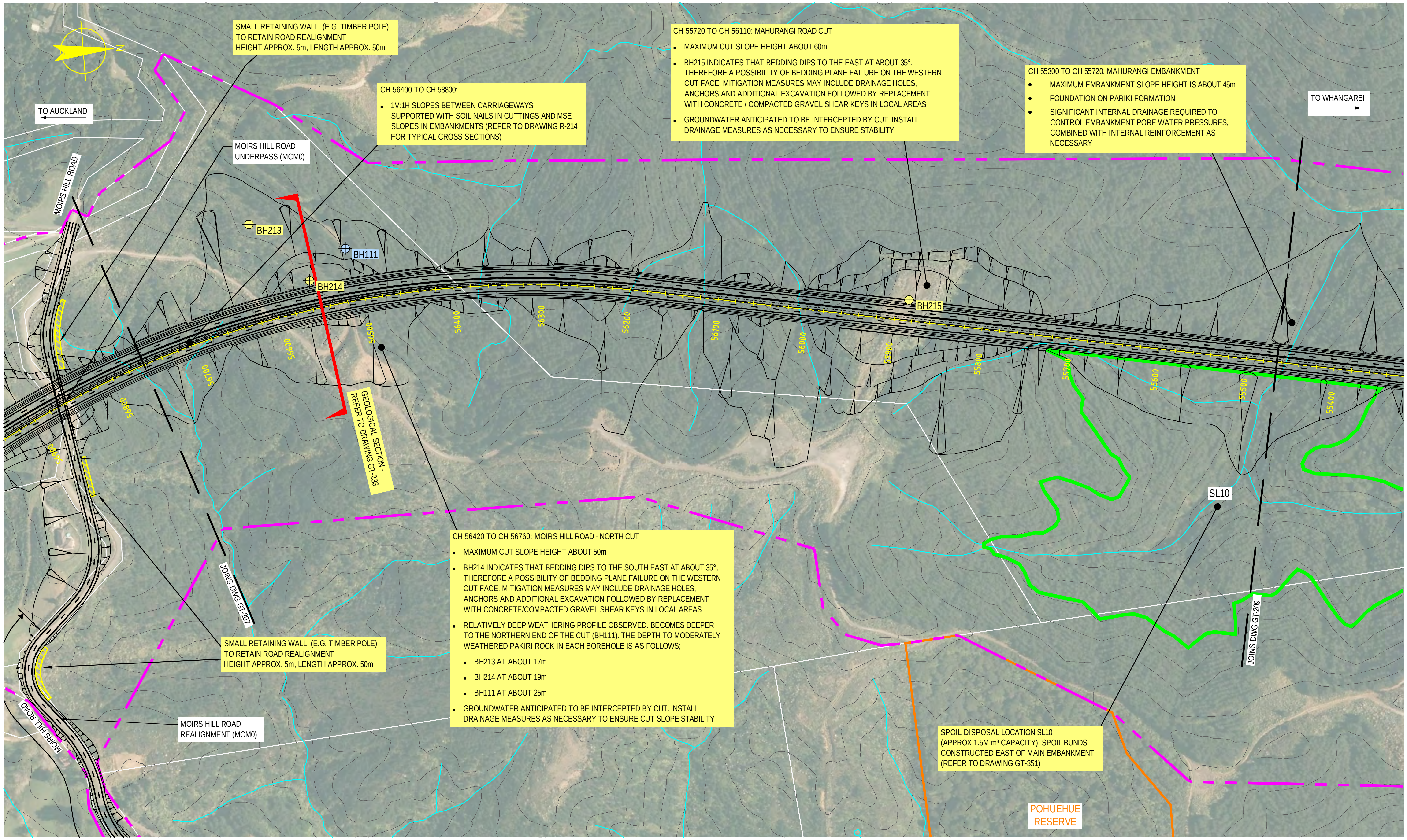
ARA TŪHONO - PŪHOI TO WELLSFORD
PŪHOI TO WARKWORTH - FOR RMA APPROVALS

DRAWN	DRAFTING CHECK	REVIEWED DISCIPLINE MANAGER	APPROVED ALLIANCE MANAGER
SNP	OJH	MRH	TI
DESIGNED: OJH	DESIGN REVIEW: DJW		

GEOTECHNICAL FEATURES
SHEET 7 OF 15

SCALE	CONTRACT No	DRAWING No	AMDT
AS SHOWN	PA3748	GT-207	0

C:\Users\MDavis\appdata\local\temp\AcPublish_4476\GT-206_GT-210.dwg Plot Date: 01 November, 2013 - 8:59 AM



NOTE: FOR GENERAL NOTES AND LEGEND, REFER TO DRAWING GT-002

0 20 40 60 80 100m
SCALE 1:4,000 @ A3 SIZE

AMD	DATE	DESIGN REVIEW	REVD D. MGR	APPD A. MGR	PURPOSE OF ISSUE / AMENDMENT
0	30/08/13	DJW	MRH	TI	ISSUE FOR NOR / CONSENT

FURTHER NORTH

DISCLAIMER
The information shown on this drawing is solely for the purposes of supporting RMA applications for statutory approvals. All information shown is subject to review for compliance with approved consents and the outcomes of final design.

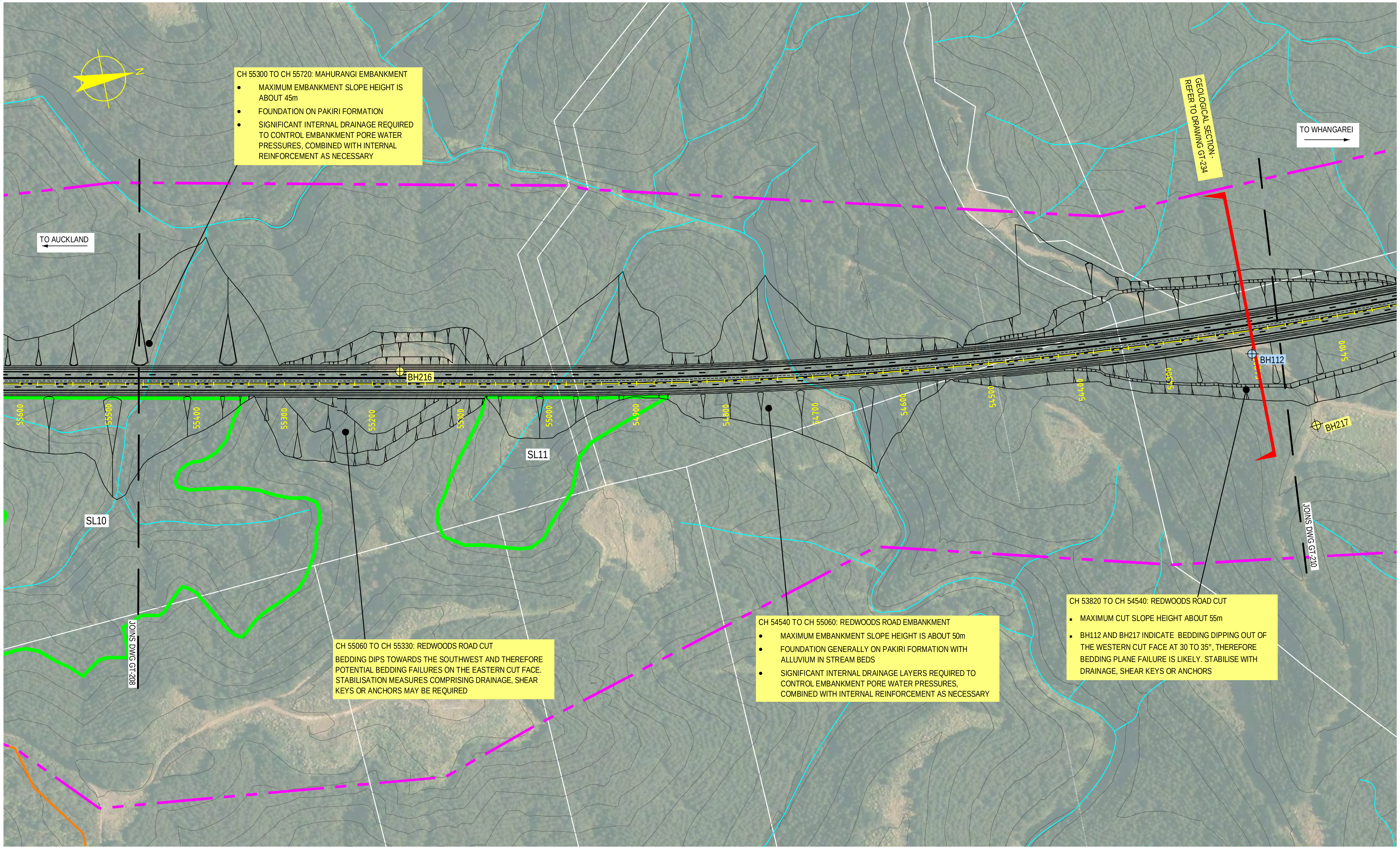
ARA TŪHONO - PŪHOI TO WELLSFORD
PŪHOI TO WARKWORTH - FOR RMA APPROVALS

DRAWN	DRAFTING CHECK	REVIEWED DISCIPLINE MANAGER	APPROVED ALLIANCE MANAGER
SNP	OJH	MRH	TI
DESIGNED: OJH	DESIGN REVIEW: DJW		

GEOTECHNICAL FEATURES
SHEET 8 OF 15

SCALE	CONTRACT No	DRAWING No	AMDT
AS SHOWN	PA3748	GT-208	0

C:\Users\MDaiv\appdata\local\temp\AcPublish_4476\GT-206_GT-210.dwg Plot Date: 01 November, 2013 - 8:56 AM



NOTE: FOR GENERAL NOTES AND LEGEND, REFER TO DRAWING GT-002

0 20 40 60 80 100m
SCALE 1:4,000 @ A3 SIZE

AMD	DATE	DESIGN REVIEW	REVD D. MGR	APPD A. MGR	PURPOSE OF ISSUE / AMENDMENT
0	30/08/13	DJW	MRH	TI	ISSUE FOR NOR / CONSENT

FURTHER NORTH

DISCLAIMER
The information shown on this drawing is solely for the purposes of supporting RMA applications for statutory approvals. All information shown is subject to review for compliance with approved consents and the outcomes of final design.

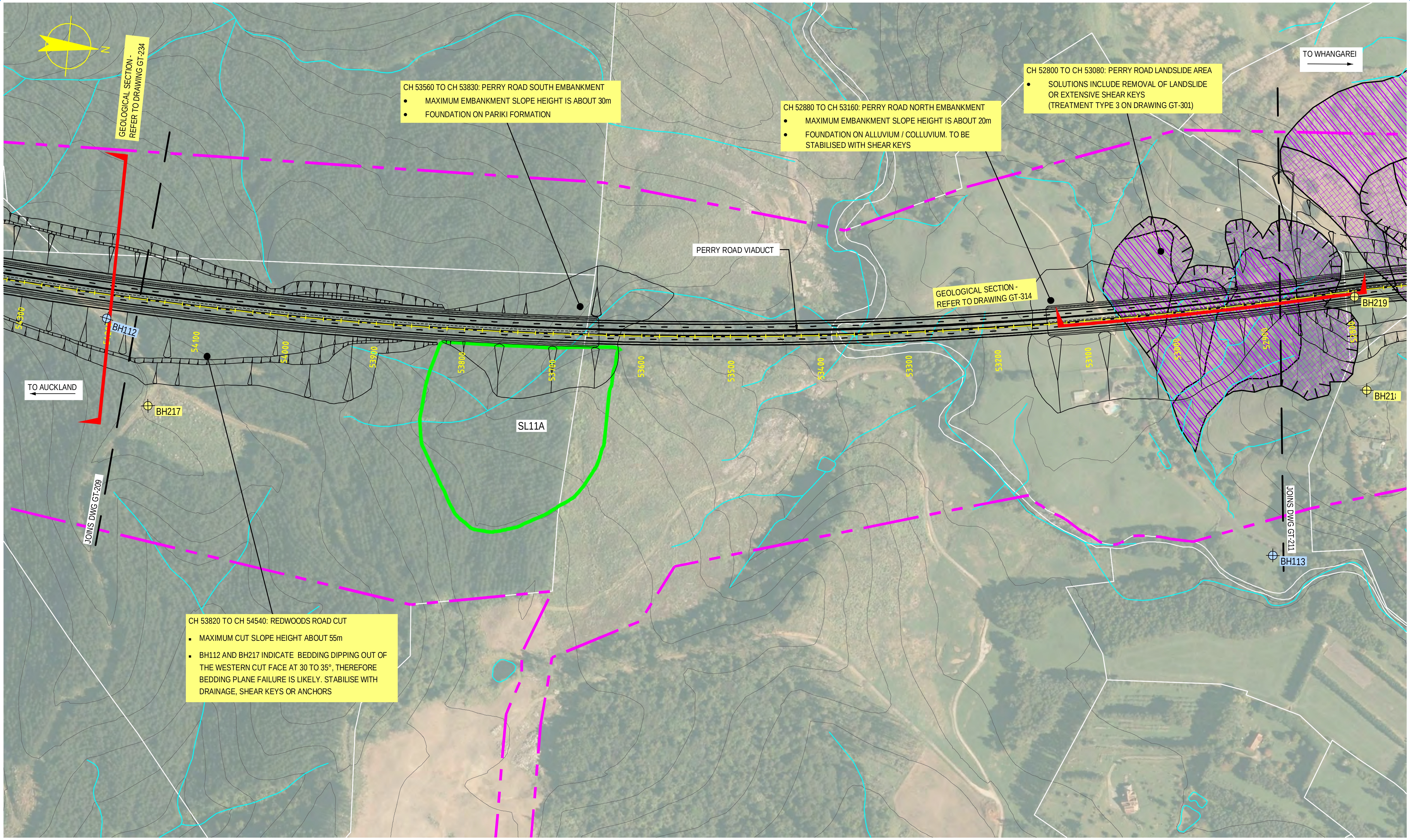
ARA TŪHONO - PŪHOI TO WELLSFORD
PŪHOI TO WARKWORTH - FOR RMA APPROVALS

DRAWN SNP | DRAFTING CHECK OJH | REVIEWED DISCIPLINE MANAGER MRH | APPROVED ALLIANCE MANAGER TI
DESIGNED OJH | DESIGN REVIEW DJW

GEOTECHNICAL FEATURES
SHEET 9 OF 15

SCALE AS SHOWN | CONTRACT No PA3748 | DRAWING No GT-209 | AMDT 0

C:\Users\MDalvi\appdata\local\temp\AcPublish_4476\GT-206_GT-210.dwg Plot Date: 01 November, 2013 - 8:59 AM



NOTE: FOR GENERAL NOTES AND LEGEND, REFER TO DRAWING GT-002

0 20 40 60 80 100m

SCALE 1:4,000 @ A3 SIZE

AMD	DATE	DESIGN REVIEW	REVD D. MGR	APPD A. MGR	PURPOSE OF ISSUE / AMENDMENT
0	30/08/13	DJW	MRH	TI	ISSUE FOR NOR / CONSENT

FURTHER NORTH

DISCLAIMER

The information shown on this drawing is solely for the purposes of supporting RMA applications for statutory approvals. All information shown is subject to review for compliance with approved consents and the outcomes of final design.

ARA TŪHONO - PŪHOI TO WELLSFORD

PŪHOI TO WARKWORTH - FOR RMA APPROVALS

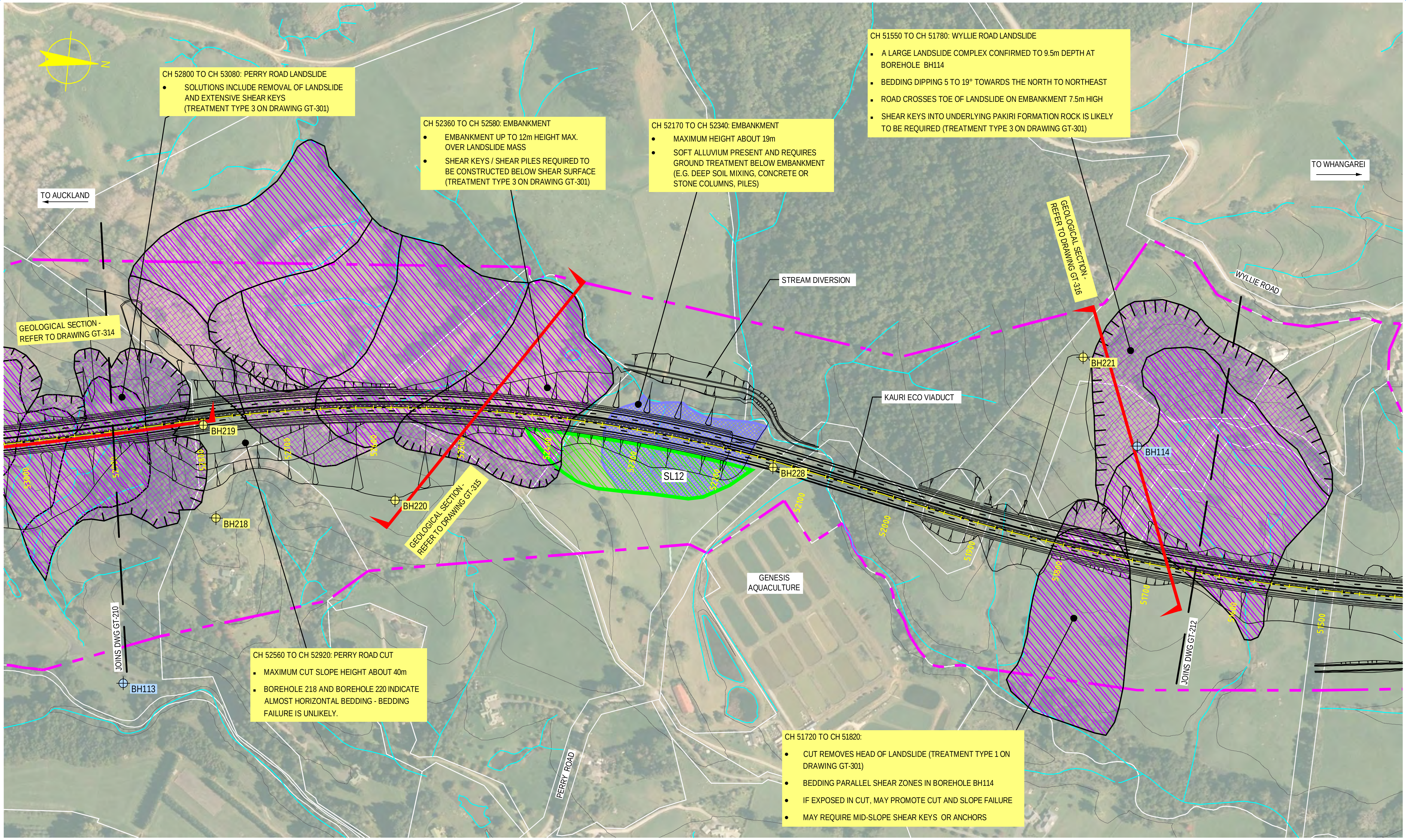
DRAWN	DRAFTING CHECK	REVIEWED DISCIPLINE MANAGER	APPROVED ALLIANCE MANAGER
SNP	OJH	MRH	TI
DESIGNED OJH	DESIGN REVIEW DJW		

GEOTECHNICAL FEATURES
SHEET 10 OF 15

SCALE	CONTRACT No	DRAWING No	AMDT
AS SHOWN	PA3748	GT-210	0

Plot Date: 01 November, 2013 - 8:50 AM

C:\Users\MDaiv\appdata\local\temp\AcPublish_4476\GT-206_GT-210.dwg



NOTE: FOR GENERAL NOTES AND LEGEND, REFER TO DRAWING GT-002

0 20 40 60 80 100m
SCALE 1:4,000 @ A3 SIZE

AMD	DATE	DESIGN REVIEW	REVD D. MGR	APPD A. MGR	PURPOSE OF ISSUE / AMENDMENT
0	30/08/13	DJW	MRH	TI	ISSUE FOR NOR / CONSENT

FURTHER NORTH

DISCLAIMER
The information shown on this drawing is solely for the purposes of supporting RMA applications for statutory approvals.
All information shown is subject to review for compliance with approved consents and the outcomes of final design.

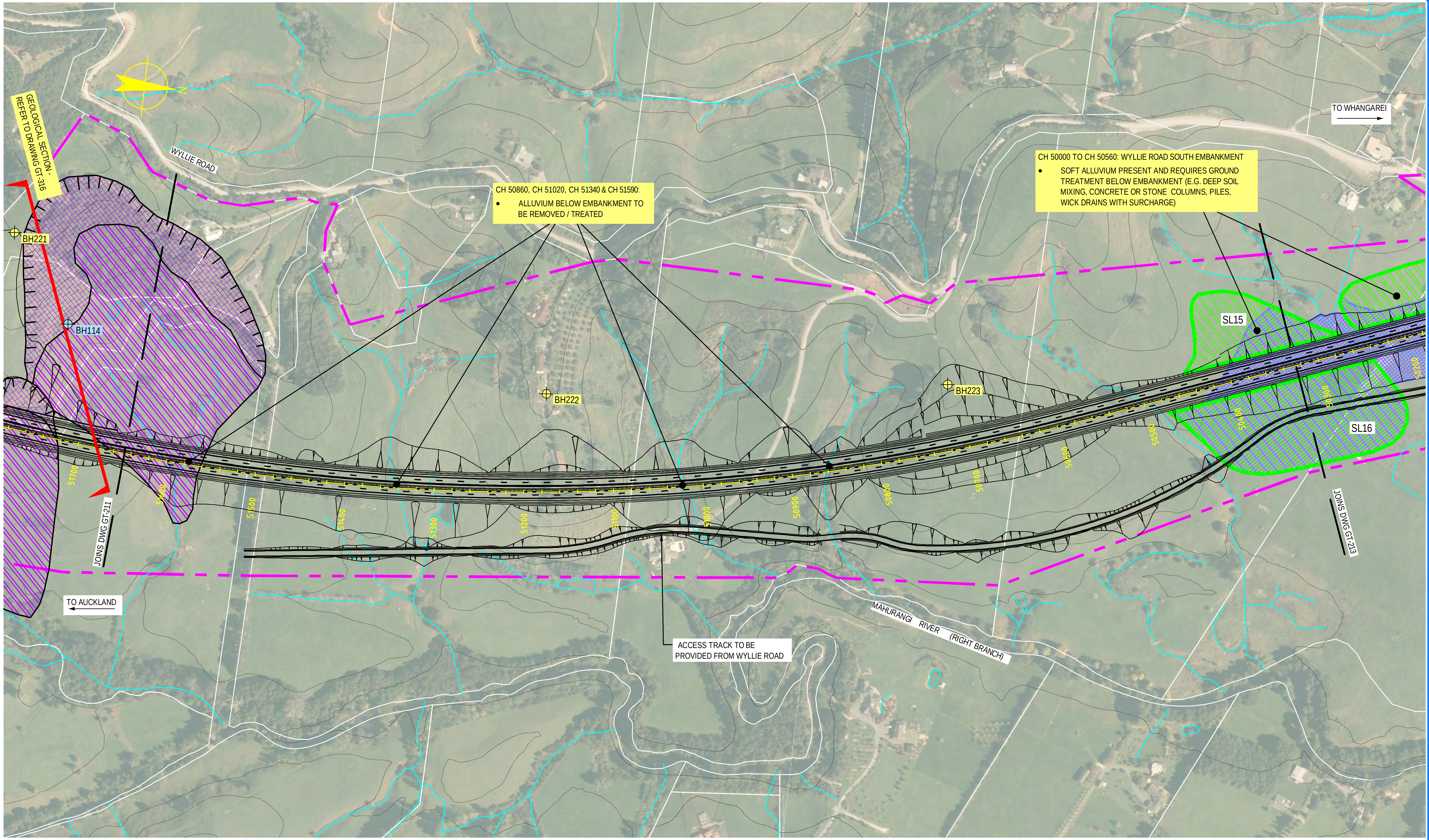
ARA TŪHONO - PŪHOI TO WELLSFORD
PŪHOI TO WARKWORTH - FOR RMA APPROVALS

DRAWN	DRAFTING CHECK	REVIEWED DISCIPLINE MANAGER	APPROVED ALLIANCE MANAGER
SNP	OJH	MRH	TI
DESIGNED OJH	DESIGN REVIEW DJW		

GEOTECHNICAL FEATURES
SHEET 11 OF 15

SCALE	CONTRACT No	DRAWING No	AMDT
AS SHOWN	PA3748	GT-211	0

S:\Further North - PAA\300 Design\300.5 Technical\01-Drawing Production\CADD\Drawings\GT-211_GT-215.dwg Plot Date: 01 November, 2013 - 9:09 AM



NOTE: FOR GENERAL NOTES AND LEGEND, REFER TO DRAWING GT-002

0 20 40 60 80 100m

SCALE 1:4,000 @ A3 SIZE

AMD	DATE	DESIGN REVIEW	REVD D. MGR	APPD A. MGR	PURPOSE OF ISSUE / AMENDMENT
0	30/08/13	DJW	MRH	TI	ISSUE FOR NOR / CONSENT

FURTHER NORTH

DISCLAIMER

The information shown on this drawing is solely for the purposes of supporting RMA applications for statutory approvals. All information shown is subject to review for compliance with approved consents and the outcomes of final design.

ARA TŪHONO - PŪHOI TO WELLSFORD

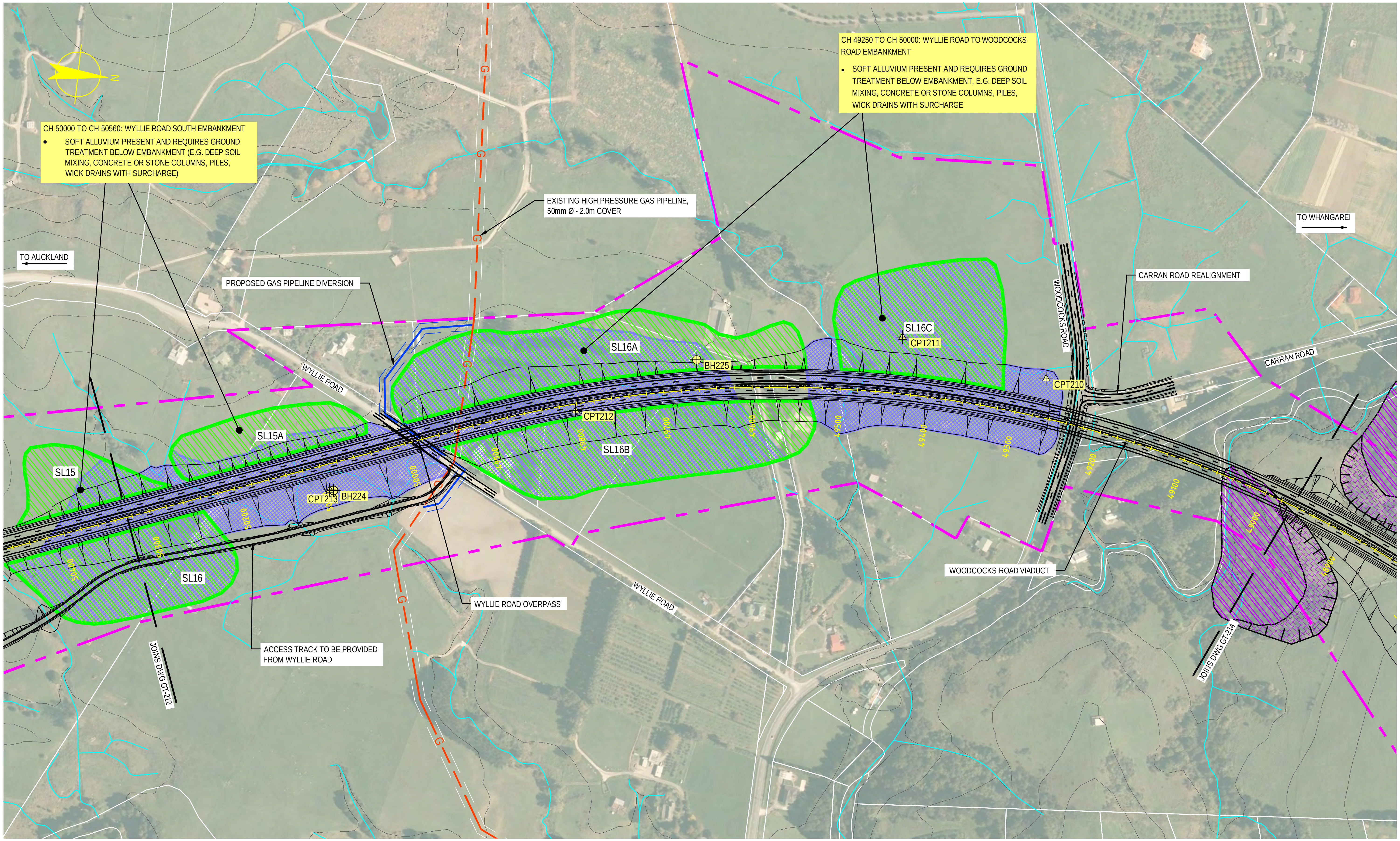
PŪHOI TO WARKWORTH - FOR RMA APPROVALS

DRAWN	DRAFTING CHECK	REVIEWED DISCIPLINE MANAGER	APPROVED ALLIANCE MANAGER
SNP	OJH	MRH	TI
DESIGNED OJH	DESIGN REVIEW DJW		

GEOTECHNICAL FEATURES
SHEET 12 OF 15

SCALE	CONTRACT No	DRAWING No	AMDT
AS SHOWN	PA3748	GT-212	0

S:\Further North - PAA\300 Design\300.5 Technical\01-Drawing Production\CADD\Drawings\GT-211_GT-215.dwg Plot Date: 01 November, 2013 - 9:10 AM



NOTE: FOR GENERAL NOTES AND LEGEND, REFER TO DRAWING GT-002

0 20 40 60 80 100m
SCALE 1:4,000 @ A3 SIZE

AMD	DATE	DESIGN REVIEW	REVD D. MGR	APPD A. MGR	PURPOSE OF ISSUE / AMENDMENT
0	30/08/13	DJW	MRH	TI	ISSUE FOR NOR / CONSENT

FURTHER NORTH

DISCLAIMER
The information shown on this drawing is solely for the purposes of supporting RMA applications for statutory approvals.
All information shown is subject to review for compliance with approved consents and the outcomes of final design.

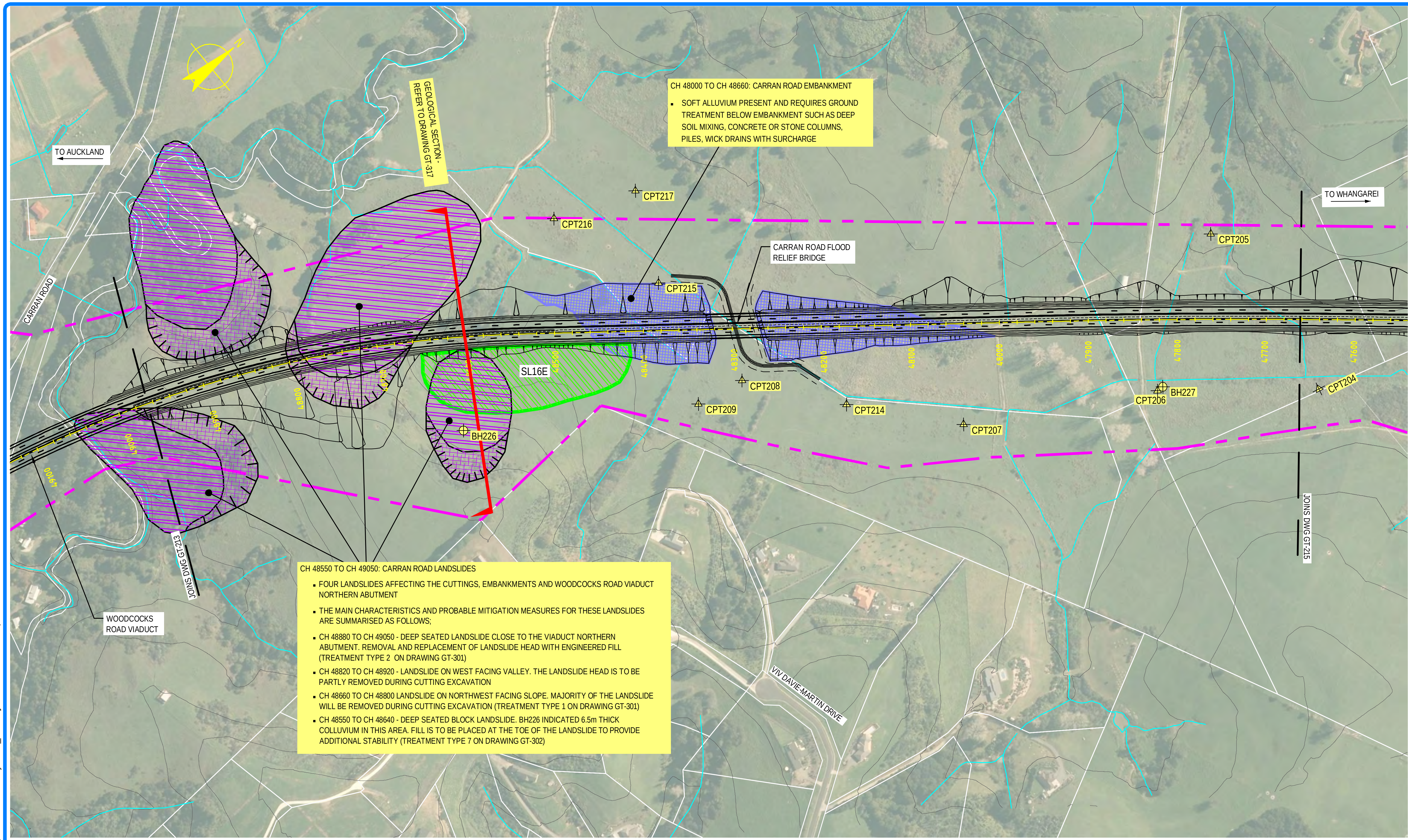
ARA TŪHONO - PŪHOI TO WELLSFORD
PŪHOI TO WARKWORTH - FOR RMA APPROVALS

DRAWN: SNP | DRAFTING CHECK: OJH | REVIEWED DISCIPLINE MANAGER: MRH | APPROVED ALLIANCE MANAGER: TI
DESIGNED: OJH | DESIGN REVIEW: DJW

GEOTECHNICAL FEATURES
SHEET 13 OF 15

SCALE: AS SHOWN | CONTRACT No: PA3748 | DRAWING No: GT-213 | AMDT: 0

S:\Further North - PAA\300 Design\300.5 Technical\01-Drawing Production\CADD\Drawings\GT-211_GT-215.dwg Plot Date: 01 November, 2013 - 9:11 AM



NOTE: FOR GENERAL NOTES AND LEGEND, REFER TO DRAWING GT-002

0 20 40 60 80 100m
SCALE 1:4,000 @ A3 SIZE

AMD	DATE	DESIGN REVIEW	REVD D. MGR	APPD A. MGR	PURPOSE OF ISSUE / AMENDMENT
0	30/08/13	DJW	MRH	TI	ISSUE FOR NOR / CONSENT

FURTHER NORTH

DISCLAIMER
The information shown on this drawing is solely for the purposes of supporting RMA applications for statutory approvals.
All information shown is subject to review for compliance with approved consents and the outcomes of final design.

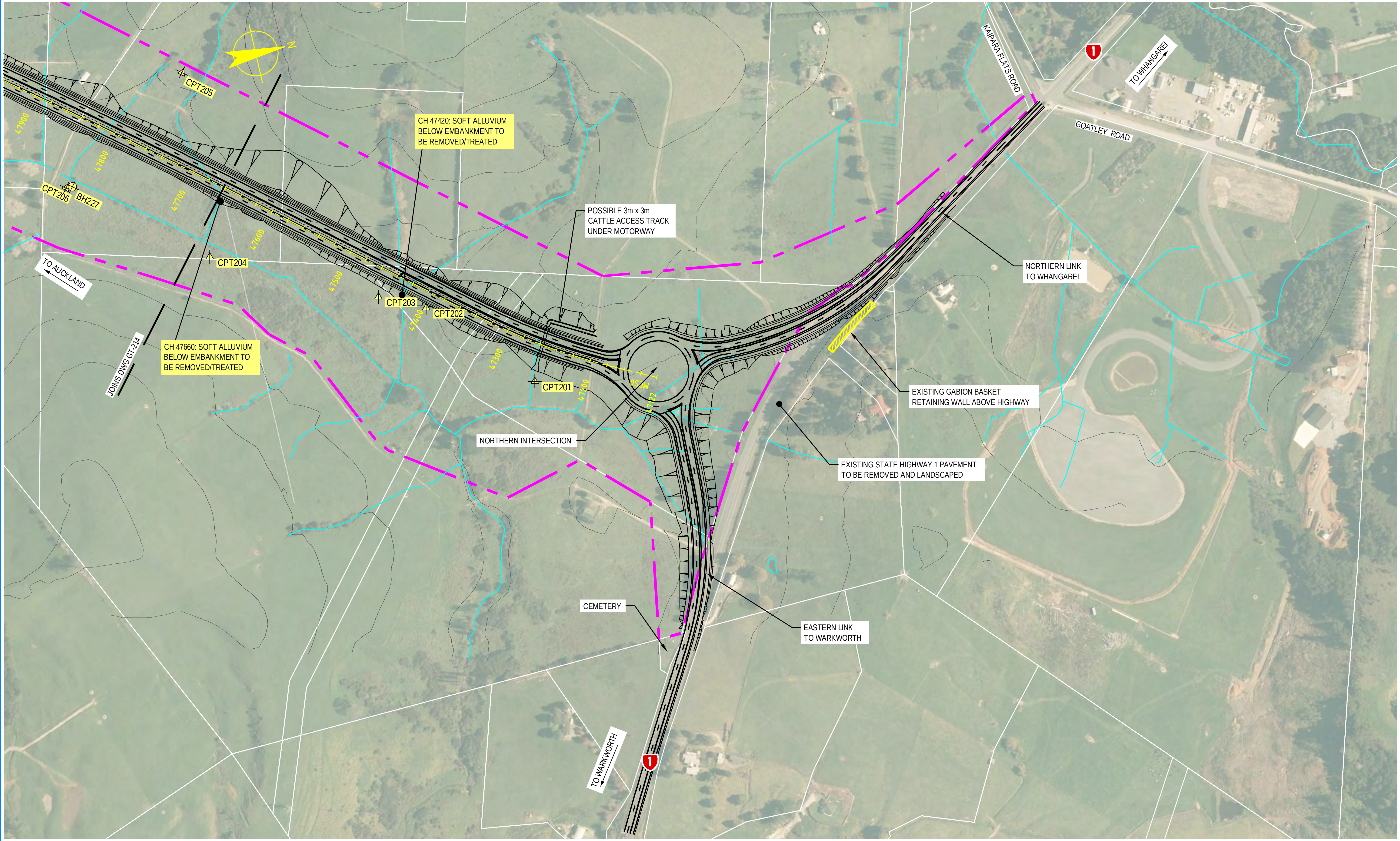
ARA TŪHONO - PŪHOI TO WELLSFORD
PŪHOI TO WARKWORTH - FOR RMA APPROVALS

DRAWN	DRAFTING CHECK	REVIEWED DISCIPLINE MANAGER	APPROVED ALLIANCE MANAGER
SNP	OJH	MRH	TI
DESIGNED: OJH	DESIGN REVIEW: DJW		

GEOTECHNICAL FEATURES
SHEET 14 OF 15

SCALE	CONTRACT No	DRAWING No	AMDT
AS SHOWN	PA3748	GT-214	0

S:\Further North - PAA\300 Design\300.5 Technical\01-Drawing Production\CADD\Drawings\GT-211_GT-215.dwg Plot Date: 01 November , 2013 - 9:13 AM



NOTE: FOR GENERAL NOTES AND LEGEND, REFER TO DRAWING GT-002

0 20 40 60 80 100m
SCALE 1:4,000 @ A3 SIZE

AMD	DATE	DESIGN REVIEW	REVD D. MGR	APPD A. MGR	PURPOSE OF ISSUE / AMENDMENT
0	30/08/13	DJW	MRH	TI	ISSUE FOR NOR / CONSENT

FURTHER NORTH

DISCLAIMER
The information shown on this drawing is solely for the purposes of supporting RMA applications for statutory approvals.
All information shown is subject to review for compliance with approved consents and the outcomes of final design.

ARA TŪHONO - PŪHOI TO WELLSFORD
PŪHOI TO WARKWORTH - FOR RMA APPROVALS

DRAWN	DRAFTING CHECK	REVIEWED DISCIPLINE MANAGER	APPROVED ALLIANCE MANAGER
SNP	OJH	MRH	TI
DESIGNED OJH	DESIGN REVIEW DJW		

GEOTECHNICAL FEATURES
SHEET 15 OF 15

SCALE	CONTRACT No	DRAWING No	AMDT
AS SHOWN	PA3748	GT-215	0

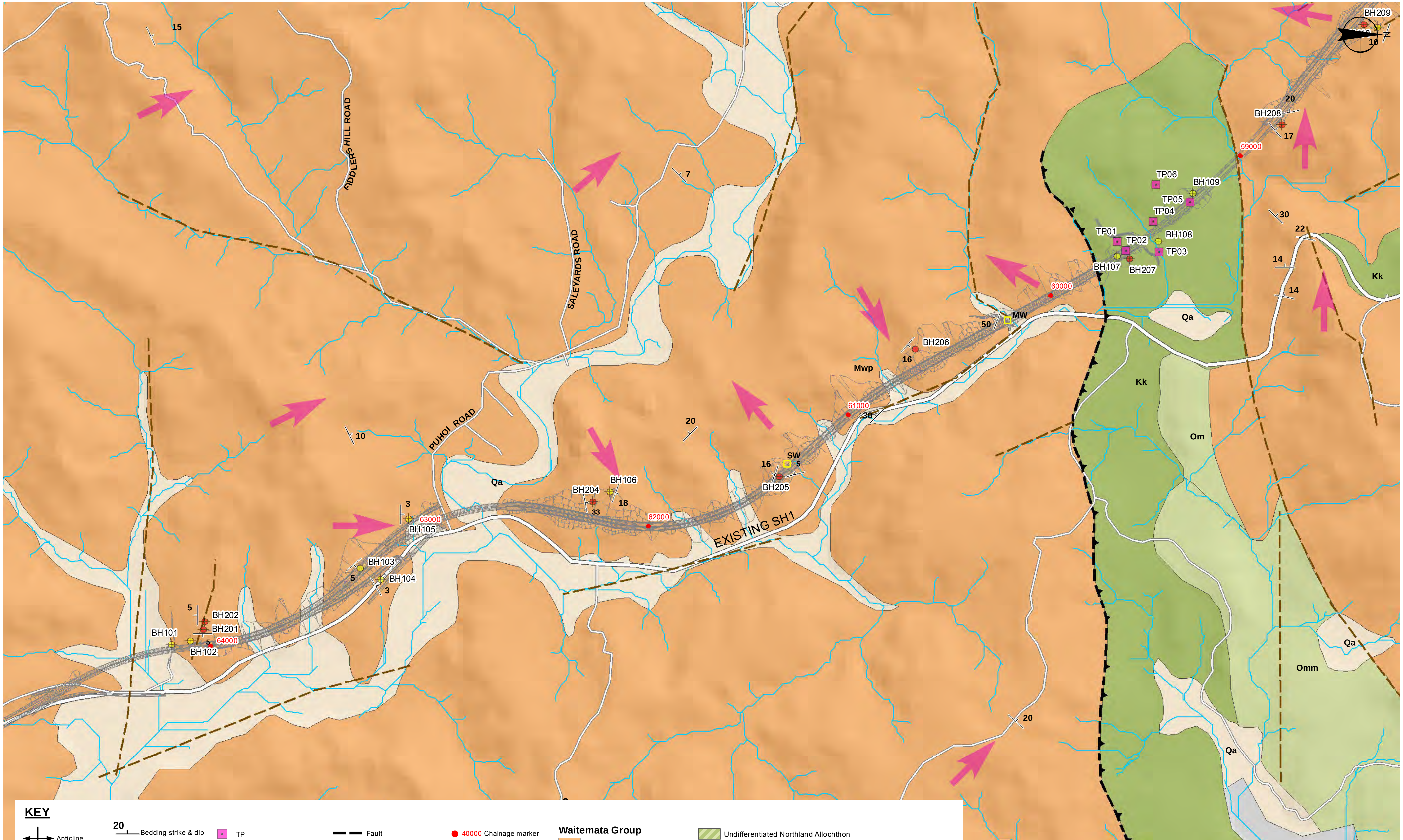
S:\Further North - PAA\300 Design\300.5 Technical\CADD\Drawings\GT-211_GT-215.dwg Plot Date: 01 November, 2013 - 9:13 AM

Appendix C. Geological Map

GT-131 Geological Map - Sheet 1 of 3

GT-132 Geological Map - Sheet 2 of 3

GT-133 Geological Map - Sheet 3 of 3



KEY

Anticline
Syncline
Generalised bedding dip direction

20 Bedding strike & dip
Horizontal bedding
Stage 1 Borehole
Stage 2 Borehole

TP
CPT

Rock Exposure

SW = Slightly Weathered
MW = Moderately Weathered

Fault
Main topographical/ geomorphic lineament
Thrust fault
Thrust fault inferred

40000 Chainage marker
Streams
Indicative alignment

Waitemata Group

Pakiri Formation (Mwp)

Northland Allochthon

Motatau Complex (Om)
Mangakahia Complex (Kk)

Undifferentiated Northland Allochthon

Alluvium

Pleistocene Alluvium/ colluvium and fan deposits (lQa)
Holocene Alluvium/ colluvium and fan deposits (Qa)
Holocene pumiceous alluvium/ colluvium with interbedded peat(EQa)

0 100 200 300 400m
SCALE 1:15,000 @ A3 SIZE

AMD	DATE	DESIGN REVIEW	REVD D. MGR	APPD A. MGR	PURPOSE OF ISSUE / AMENDMENT
0	30/08/13	DJW	MRH	TI	ISSUE FOR NOR / CONSENT

FURTHER NORTH

DISCLAIMER

The information shown on this drawing is solely for the purposes of supporting RMA applications for statutory approvals. AI information shown is subject to review for compliance with approved consents and the outcomes of final design.

ARA TŪHONO - PŪHOI TO WELLSFORD

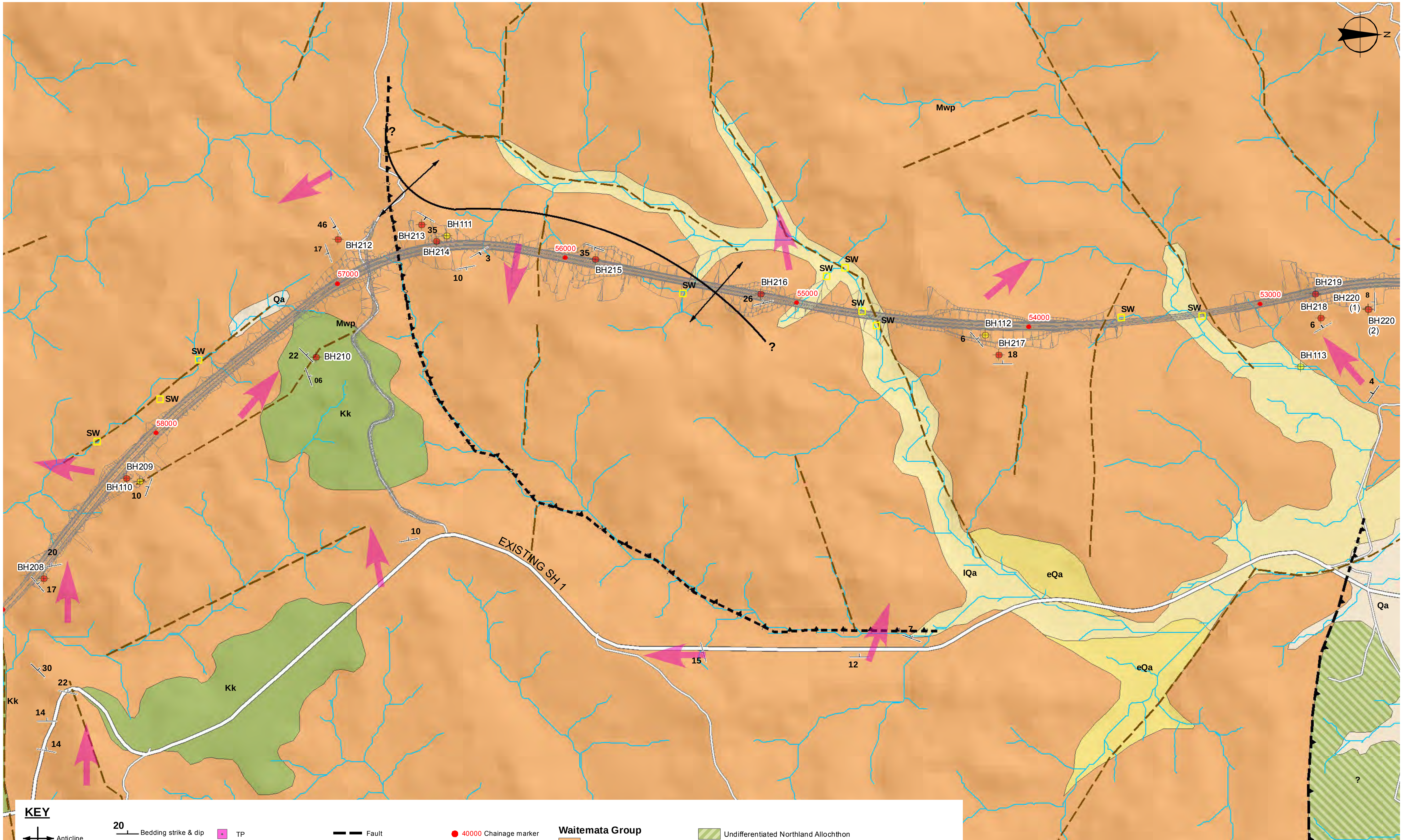
PŪHOI TO WARKWORTH - FOR RMA APPROVALS

DRAWN	DRAFTING CHECK	REVIEWED DISCIPLINE MANAGER	APPROVED ALLIANCE MANAGER
JW	RGK	MRH	TI
DESIGNED	DESIGN REVIEW		
RGK	DJW		

GEOLOGICAL MAP

SHEET 1 OF 3

SCALE	CONTRACT No	DRAWING No	AMDT
AS SHOWN	PA3748	GT-131	0



KEY

- Anticline
- Syncline
- Generalised bedding dip direction
- 20 Bedding strike & dip
- Horizontal bedding
- Stage 1 Borehole
- Stage 2 Borehole
- TP
- CPT

Rock Exposure

- SW = Slightly Weathered
- MW = Moderately Weathered
- Fault
- Main topographical/ geomorphic lineament
- Thrust fault
- Thrust fault inferred
- 40000 Chainage marker
- Streams
- Indicative alignment

Waitemata Group

- Pakiri Formation (Mwp)

Northland Allochthon

- Motatau Complex (Om)
- Mangakahia Complex (Kk)
- Undifferentiated Northland Allochthon

Alluvium

- Pleistocene Alluvium/ colluvium and fan deposits (IQa)
- Holocene Alluvium/ colluvium and fan deposits (Qa)
- Holocene pumiceous alluvium/ colluvium with interbedded peat(EQa)

0 100 200 300 400m
SCALE 1:15,000 @ A3 SIZE

AMD	DATE	DESIGN REVIEW	REVD D. MGR	APPD A. MGR	PURPOSE OF ISSUE / AMENDMENT
0	30/08/13	DJW	MRH	TI	ISSUE FOR NOR / CONSENT

FURTHER NORTH

DISCLAIMER
The information shown on this drawing is solely for the purposes of supporting RMA applications for statutory approvals.
Al information shown is subject to review for compliance with approved consents and the outcomes of final design.

ARA TŪHONO - PŪHOI TO WELLSFORD

PŪHOI TO WARKWORTH - FOR RMA APPROVALS

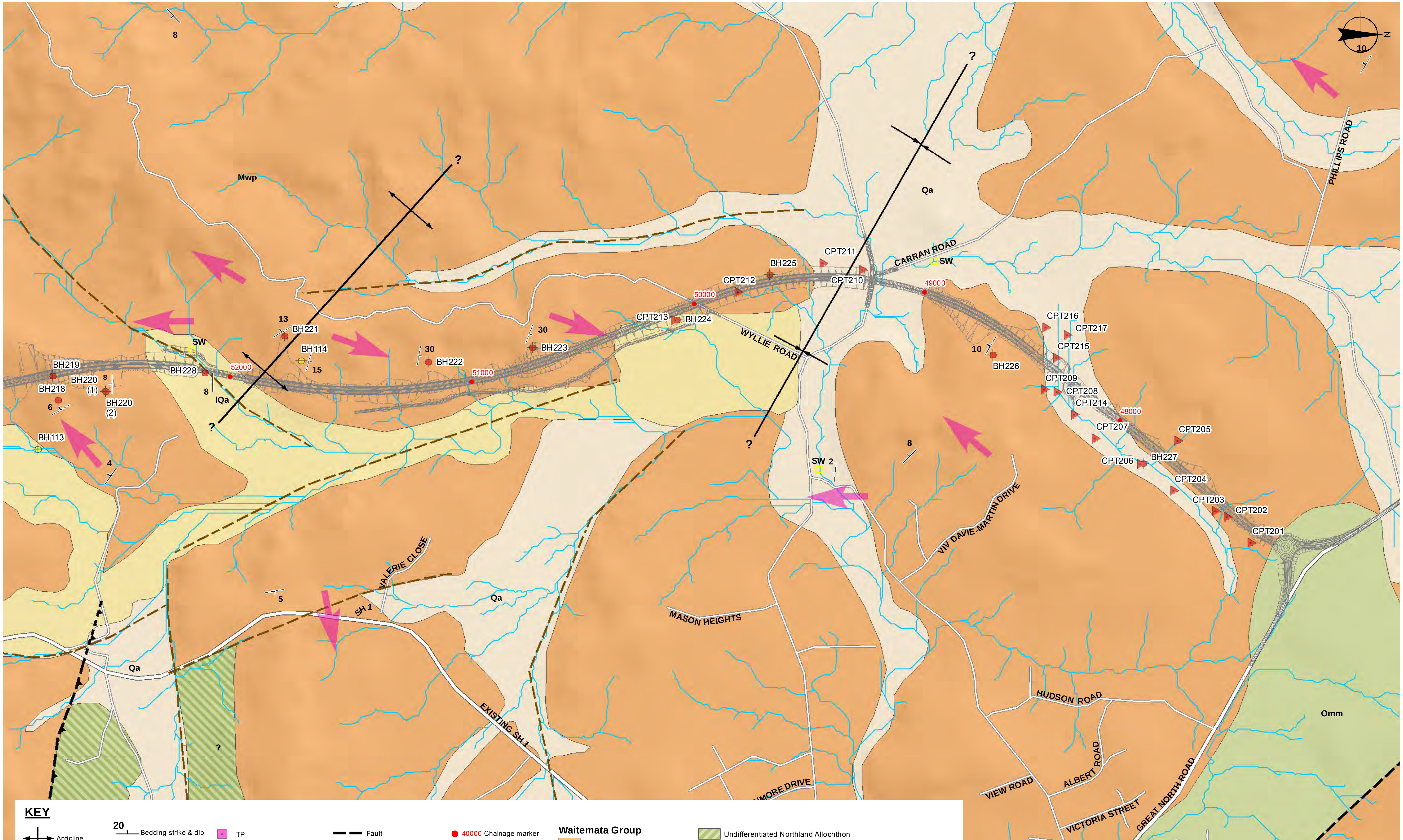
DRAWN	DRAFTING CHECK	REVIEWED DISCIPLINE MANAGER	APPROVED ALLIANCE MANAGER
JW	RGK	MRH	TI
DESIGNED: RGK	DESIGN REVIEW: DJW		

GEOLOGICAL MAP

SHEET 2 OF 3

SCALE	CONTRACT No	DRAWING No	AMDT
AS SHOWN	PA3748	GT-132	0

Date: 22/10/2013 Time: 2:43:02 PM



KEY

Anticline

Syncline

Generalised bedding dip direction

20 Bedding strike & dip

Horizontal bedding

Stage 1 Borehole

Stage 2 Borehole

TP

CPT

Rock Exposure

SW = Slightly Weathered
MW = Moderately Weathered

Fault

Main topographical/ geomorphic lineament

Thrust fault

Thrust fault inferred

40000 Chainage marker

Streams

Indicative alignment

Waitemata Group

Pakiri Formation (Mwp)

Northland Allochthon

Motatau Complex (Om)

Mangakahia Complex (Kk)

Undifferentiated Northland Allochthon

Alluvium

Pleistocene Alluvium/ colluvium and fan deposits (IQa)

Holocene Alluvium/ colluvium and fan deposits (Qa)

Holocene pumiceous alluvium/ colluvium with interbedded peat(EQa)

0 100 200 300 400m
SCALE 1:15,000 @ A3 SIZE

AMD	DATE	DESIGN REVIEW	REVD D. MGR	APPD A. MGR	PURPOSE OF ISSUE / AMENDMENT
0	30/08/13	DJW	MRH	TI	ISSUE FOR NOR / CONSENT

FURTHER NORTH

DISCLAIMER
The information shown on this drawing is solely for the purposes of supporting RMA applications for statutory approvals.
Al information shown is subject to review for compliance with approved consents and the outcomes of final design.

ARA TŪHONO - PŪHOI TO WELLSFORD

PŪHOI TO WARKWORTH - FOR RMA APPROVALS

DRAWN	DRAFTING CHECK	REVIEWED DISCIPLINE MANAGER	APPROVED ALLIANCE MANAGER
JW	RGK	MRH	TI
DESIGNED: RGK	DESIGN REVIEW: DJW		

GEOLOGICAL MAP

SHEET 3 OF 3

SCALE	CONTRACT No	DRAWING No	AMDT
AS SHOWN	PA3748	GT-133	0

Path: S:\Further North - PAA\300 Design\300.5 Technical\10 GIS\MXD\Z_REPORT_FIGURES\GEOTECHNICAL\GT131_133.mxd

Appendix D. Engineering Geological Appraisal Field Map

GT-001	Engineering Geological Appraisal Map - Notes and Legend
GT-100	Engineering Geological Appraisal Map - Sheet Layout
GT-101	Engineering Geological Appraisal Map - Sheet 1 of 17
GT-102	Engineering Geological Appraisal Map - Sheet 2 of 17
GT-103	Engineering Geological Appraisal Map - Sheet 3 of 17
GT-104	Engineering Geological Appraisal Map - Sheet 4 of 17
GT-105	Engineering Geological Appraisal Map - Sheet 5 of 17
GT-106	Engineering Geological Appraisal Map - Sheet 6 of 17
GT-107	Engineering Geological Appraisal Map - Sheet 7 of 17
GT-108	Engineering Geological Appraisal Map - Sheet 8 of 17
GT-109	Engineering Geological Appraisal Map - Sheet 9 of 17
GT-110	Engineering Geological Appraisal Map - Sheet 10 of 17
GT-111	Engineering Geological Appraisal Map - Sheet 11 of 17
GT-112	Engineering Geological Appraisal Map - Sheet 12 of 17
GT-113	Engineering Geological Appraisal Map - Sheet 13 of 17
GT-114	Engineering Geological Appraisal Map - Sheet 14 of 17
GT-115	Engineering Geological Appraisal Map - Sheet 15 of 17
GT-116	Engineering Geological Appraisal Map - Sheet 16 of 17
GT-117	Engineering Geological Appraisal Map - Sheet 17 of 17

MAP LEGEND

- PROPOSED DESIGNATION BOUNDARY
- CONTROL LINE AND CHAINAGE (65000, 64900)
- <---- CUT SLOPES
- <----- INDICATIVE ROAD ALIGNMENT
- <----- FILL SLOPES
- MADE GROUND
- MARSH / ESTUARINE ALLUVIUM
- POND
- STREAM (WITH DIRECTION ARROW)
- SPRING
- RIVER TERRACE
- SURFACE SLOPE (IN DEGREES) (10)
- SCARP - SHARP
- BREAK OF SLOPE - SHARP - CONVEX
- BREAK OF SLOPE - SHARP - CONCAVE
- BREAK OF SLOPE - ROUNDED - CONVEX
- BREAK OF SLOPE - ROUNDED - CONCAVE
- RIDGELINE (OR —R—R—R—)
- STRIKE AND DIP-INCLINED BEDDING (DIP IN DEGREES) (20)
- HORIZONTAL BEDDING
- LANDSLIDE (TYPE UNDETERMINED)
- ROTATIONAL LANDSLIDE (WITH BACKTILT)
- SUCCESSIVE ROTATIONAL LANDSLIDES
- TRANSLATIONAL LANDSLIDE
- LANDSLIDE (WITH GRABEN)
- FLOW SLIDE
- TOPOGRAPHICAL LINEAMENT (—L—L—L)
- UNDULATIONS / HUMMOCKY GROUND
- TERRACETTES
- FIELD MAPPING REFERENCE LOCATIONS (DETAILED DESCRIPTION / NOTES ARE IN FIELD NOTEBOOKS NOT INCLUDED IN THIS REPORT) (LW4)

FIELD MAP ABBREVIATIONS

L	=	LANDSLIDE (TYPE UNDERMINED)
Lt	=	TRANSLATIONAL LANDSLIDE
Lr	=	ROTATIONAL LANDSLIDE
Lf	=	FLOW LANDSLIDE
Lb	=	BLOCK SLIDE
Ls	=	SHALLOW LANDSLIDE (ESTIMATED <5m)
Ld	=	DEEP LANDSLIDE (ESTIMATED >5m)
C	=	COLLUVIUM (Undifferentiated fine slope debris)
T	=	TALLUVIUM (Undifferentiated course slope debris)
A	=	FILL
Qa	=	HOLOCENE ALLUVIUM
Qf	=	UNDIFFERENTIATED HOLOCENE ALLUVIAL / COLLUVIAL FAN DEPOSITS
Ta	=	INCISED ALLUVIAL RIVER TERRACES
P	=	PAKIRI FORMATION
NA	=	NORTHERN ALLOCHTHON - UNDIFFERENTIATED
Kk	=	NORTHERN ALLOCHTHON - MANGAKAHIA COMPLEX
Omm	=	NORTHERN ALLOCHTHON - MAHURANGI LIMESTONE

NOTES

1. ENGINEERING GEOLOGICAL APPRAISAL MAP SHEETS 1 TO 17 (DRAWINGS GT-101 TO GT-117) COMPRISE MULTIPLE FIELD MAP SHEETS PREPARED AT 1:5000 SCALE. SOME MINOR DISCREPANCIES MAY EXIST AT BOUNDARY EDGES OF FIELD MAP SHEETS.
2. THE ENGINEERING GEOLOGICAL APPRAISAL MAPS SHOW MAIN GEOMORPHOLOGICAL AND ENGINEERING GEOLOGICAL FEATURES, IDENTIFIED FROM AERIAL PHOTOGRAPH INTERPRETATION AND FIELD MAPPING.
3. FIELD MAPPING REFERENCE LOCATIONS (SYMBOLS / TEXT IN RED) INCLUDED ON THE MAPS ARE FOR INTERNAL REFERENCE ONLY. DETAILED DESCRIPTIONS / NOTES ARE NOT INCLUDED IN THE GEOTECHNICAL APPRAISAL REPORT.

AMD	DATE	DESIGN REVIEW	REV'D D. MGR	APP'D A. MGR	PURPOSE OF ISSUE / AMENDMENT
0	30/08/13	DJW	MRH	TI	ISSUE FOR NOR / CONSENT

FURTHER NORTH

DISCLAIMER
The information shown on this drawing is solely for the purposes of supporting RMA applications for statutory approvals.
All information shown is subject to review for compliance with approved consents and the outcomes of final design.

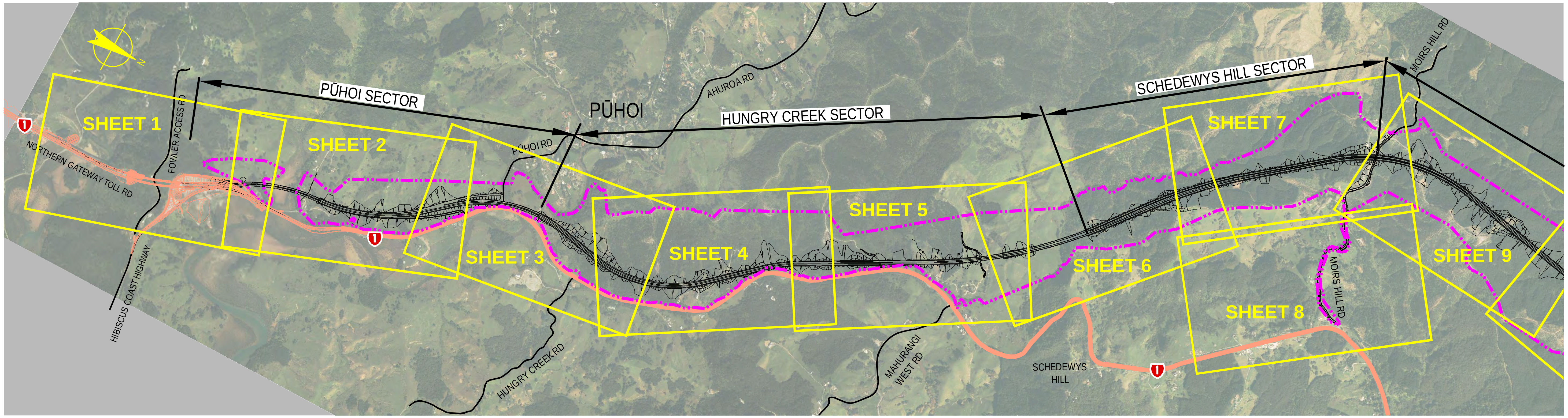
ARA TŪHONO - PŪHOI TO WELLSFORD
PŪHOI TO WARKWORTH - FOR RMA APPROVALS

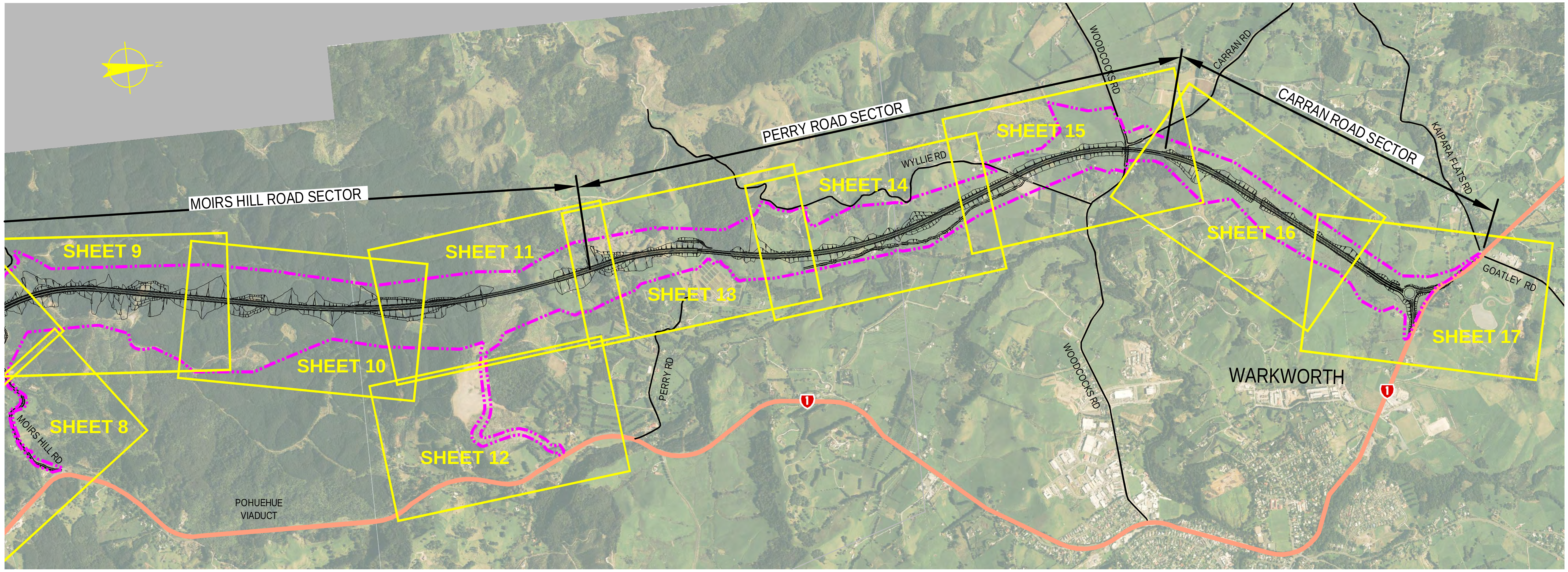
DRAWN	DRAFTING CHECK	REVIEWED DISCIPLINE MANAGER	APPROVED ALLIANCE MANAGER
SNP	RGK	MRH	TI
DESIGNED: RGK	DESIGN REVIEW: DJW		

ENGINEERING GEOLOGICAL APPRAISAL MAP
NOTES AND LEGEND

SCALE	CONTRACT No	DRAWING No	AMDT
NOT TO SCALE	PA3748	GT-001	0

C:\Users\MDalvi\appdata\local\temp\AcPublish_5284\GT-001.dwg Plot Date: 24 September , 2013 - 10:01 AM





S:\Further North - PAA\300 Design\300.5 Technical\01-Drawing Production\CADD\Drawings\GT-100.dwg Plot Date: 29 August, 2013 - 12:09 PM

AMD	DATE	DESIGN REVIEW	REV'D D. MGR	APP'D A. MGR	PURPOSE OF ISSUE / AMENDMENT
0	30/08/13	DJW	MRH	TI	ISSUE FOR NOR / CONSENT

FURTHER NORTH

DISCLAIMER
The information shown on this drawing is solely for the purposes of supporting RMA applications for statutory approvals.
All information shown is subject to review for compliance with approved consents and the outcomes of final design.

ARA TŪHONO - PŪHOI TO WELLSFORD

PŪHOI TO WARKWORTH - FOR RMA APPROVALS

DRAWN	DRAFTING CHECK	REVIEWED DISCIPLINE MANAGER	APPROVED ALLIANCE MANAGER
SNP	RGK	MRH	TI
DESIGNED RGK	DESIGN REVIEW DJW		

ENGINEERING GEOLOGICAL APPRAISAL MAP
SHEET LAYOUT

SCALE	CONTRACT No	DRAWING No	AMDT
NOT TO SCALE	PA3748	GT-100	0

NOTE: FOR GENERAL NOTES AND LEGEND, REFER TO DRAWING GT-001

0 20 40 60 80 100m
SCALE 1:4,000 @ A3 SIZE

AMD	DATE	DESIGN REVIEW	REVD D. MGR	APPD A. MGR	PURPOSE OF ISSUE / AMENDMENT
0	30/08/13	DJW	MRH	TI	ISSUE FOR NOR / CONSENT

FURTHER NORTH

DISCLAIMER
The information shown on this drawing is solely for the purposes of supporting RMA applications for statutory approvals.
All information shown is subject to review for compliance with approved consents and the outcomes of final design.

ARA TŪHONO - PŪHOI TO WELLSFORD

PŪHOI TO WARKWORTH - FOR RMA APPROVALS

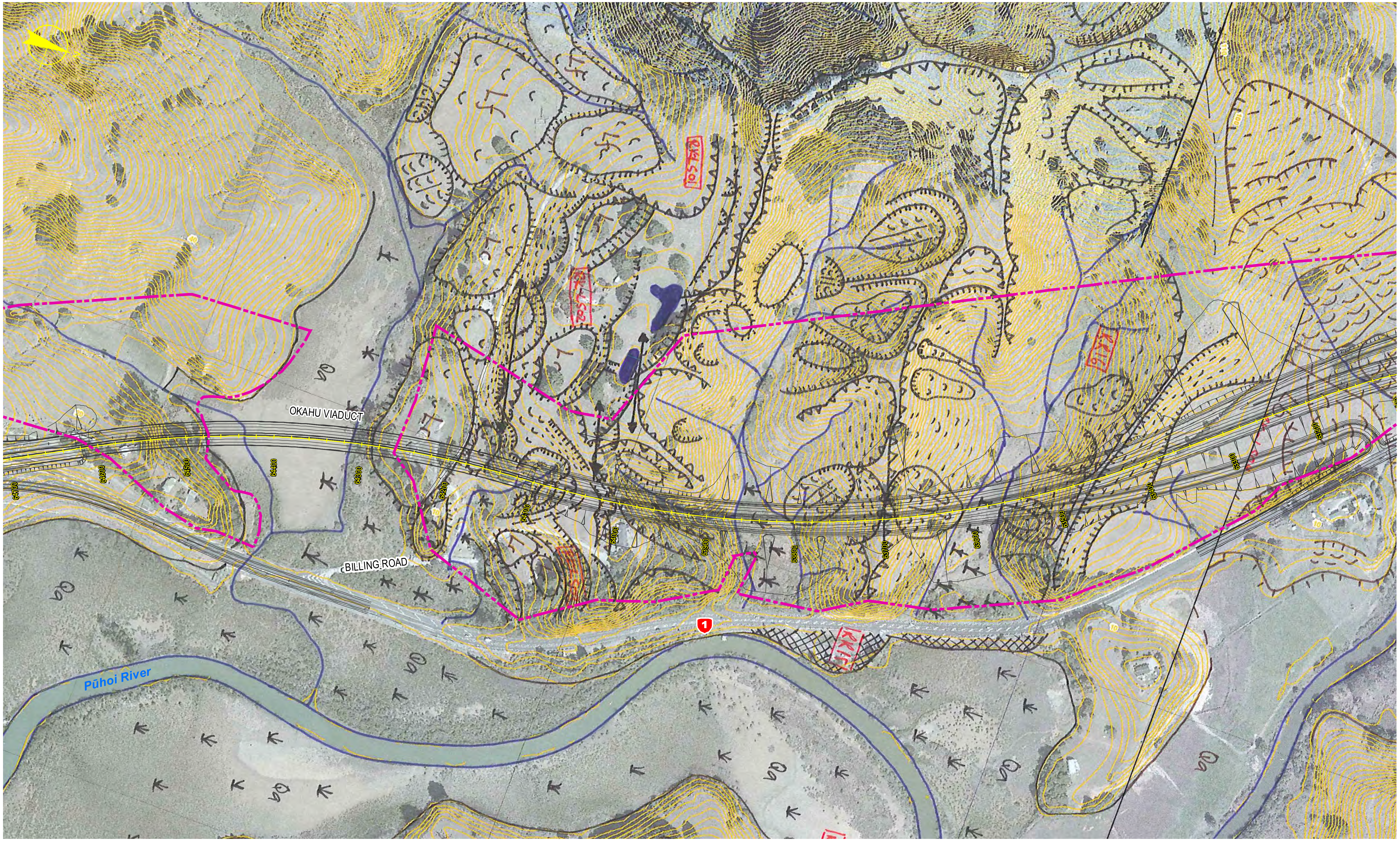
DRAWN	REVIEWED	REVIEWED DISCIPLINE MANAGER	APPROVED ALLIANCE MANAGER
JW	RGK	MRH	TI
DESIGNED: RGK	DESIGN REVIEW: DJW		

ENGINEERING GEOLOGICAL APPRAISAL MAP
SHEET 1 OF 17

SCALE	CONTRACT No	DRAWING No	AMDT
AS SHOWN	PA3748	GT-101	0

Date: 16/10/2013 Time: 8:40:25 AM

Path: S:\Further North - PAA\300 Design\300.5 Technical\10 GIS\MXD\2_REPORT_FIGURES\GEOTECHNICAL\GT101_117.mxd



NOTE: FOR GENERAL NOTES AND LEGEND, REFER TO DRAWING GT-001

0 20 40 60 80 100m
SCALE 1:4,000 @ A3 SIZE

AMD	DATE	DESIGN REVIEW	REVD. D. MGR	APPD A. MGR	PURPOSE OF ISSUE / AMENDMENT
0	30/08/13	DJW	MRH	TI	ISSUE FOR NOR / CONSENT

FURTHER NORTH

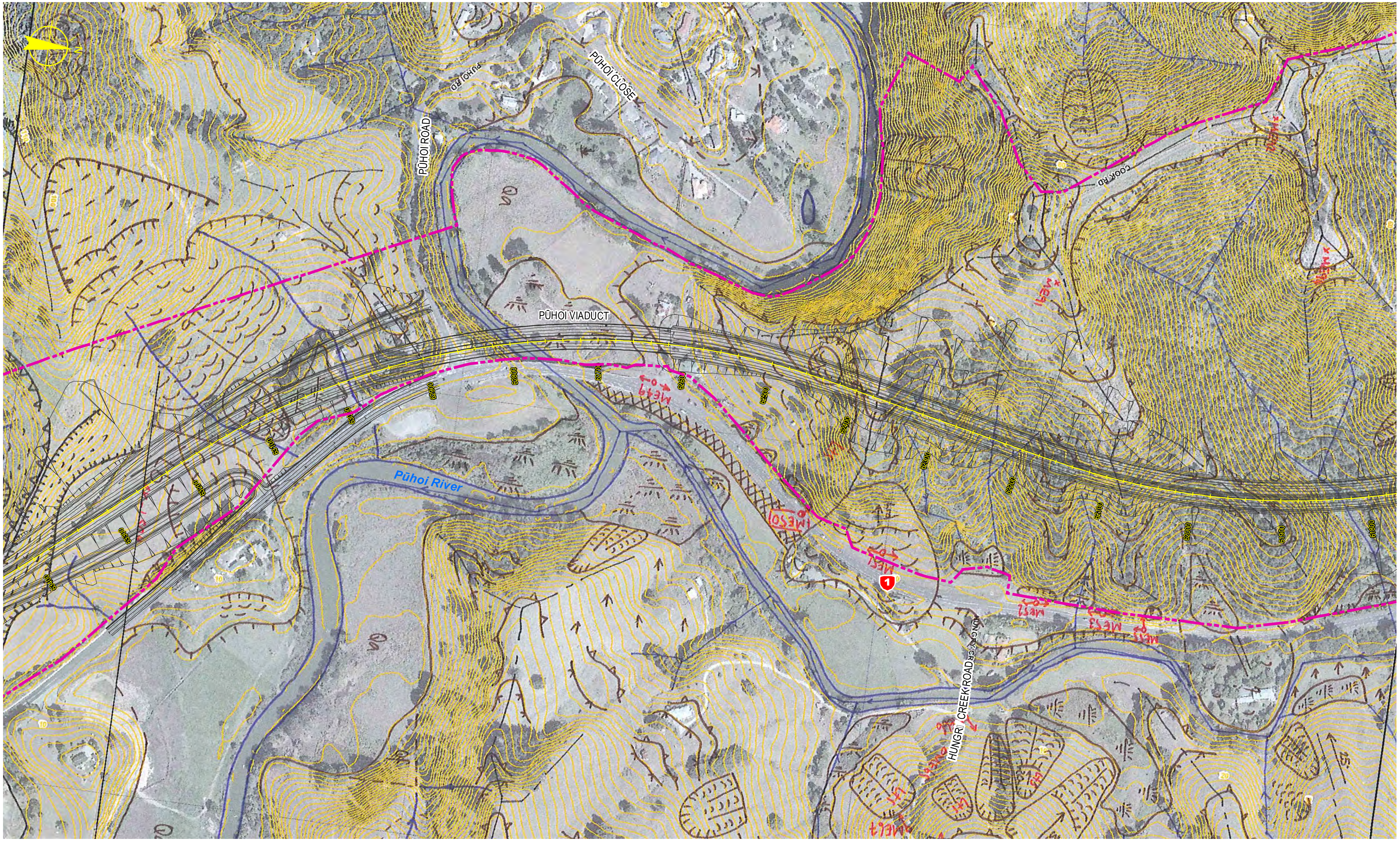
DISCLAIMER
The information shown on this drawing is solely for the purposes of supporting RMA applications for statutory approvals. All information shown is subject to review for compliance with approved consents and the outcomes of final design.

ARA TŪHONO - PŪHOI TO WELLSFORD
PŪHOI TO WARKWORTH - FOR RMA APPROVALS

DRAWN	REVIEWED	REVIEWED DISCIPLINE MANAGER	APPROVED ALLIANCE MANAGER
JW	RGK	MRH	TI
DESIGNED RGK	DESIGN REVIEW DJW		

ENGINEERING GEOLOGICAL APPRAISAL MAP
SHEET 2 OF 17

SCALE	CONTRACT No.	DRAWING No.	AMDT
AS SHOWN	PA3748	GT-102	0



NOTE: FOR GENERAL NOTES AND LEGEND, REFER TO DRAWING GT-001

SCALE 1:4,000 @ A3 SIZE

AMD	DATE	DESIGN REVIEW	REVD D. MGR	APPD A. MGR	PURPOSE OF ISSUE / AMENDMENT
0	30/08/13	DJW	MRH	TI	ISSUE FOR NOR / CONSENT

FURTHER NORTH

DISCLAIMER

The information shown on this drawing is solely for the purposes of supporting RMA applications for statutory approvals. All information shown is subject to review for compliance with approved consents and the outcomes of final design.

ARA TŪHONO - PŪHOI TO WELLSFORD

PŪHOI TO WARKWORTH - FOR RMA APPROVALS

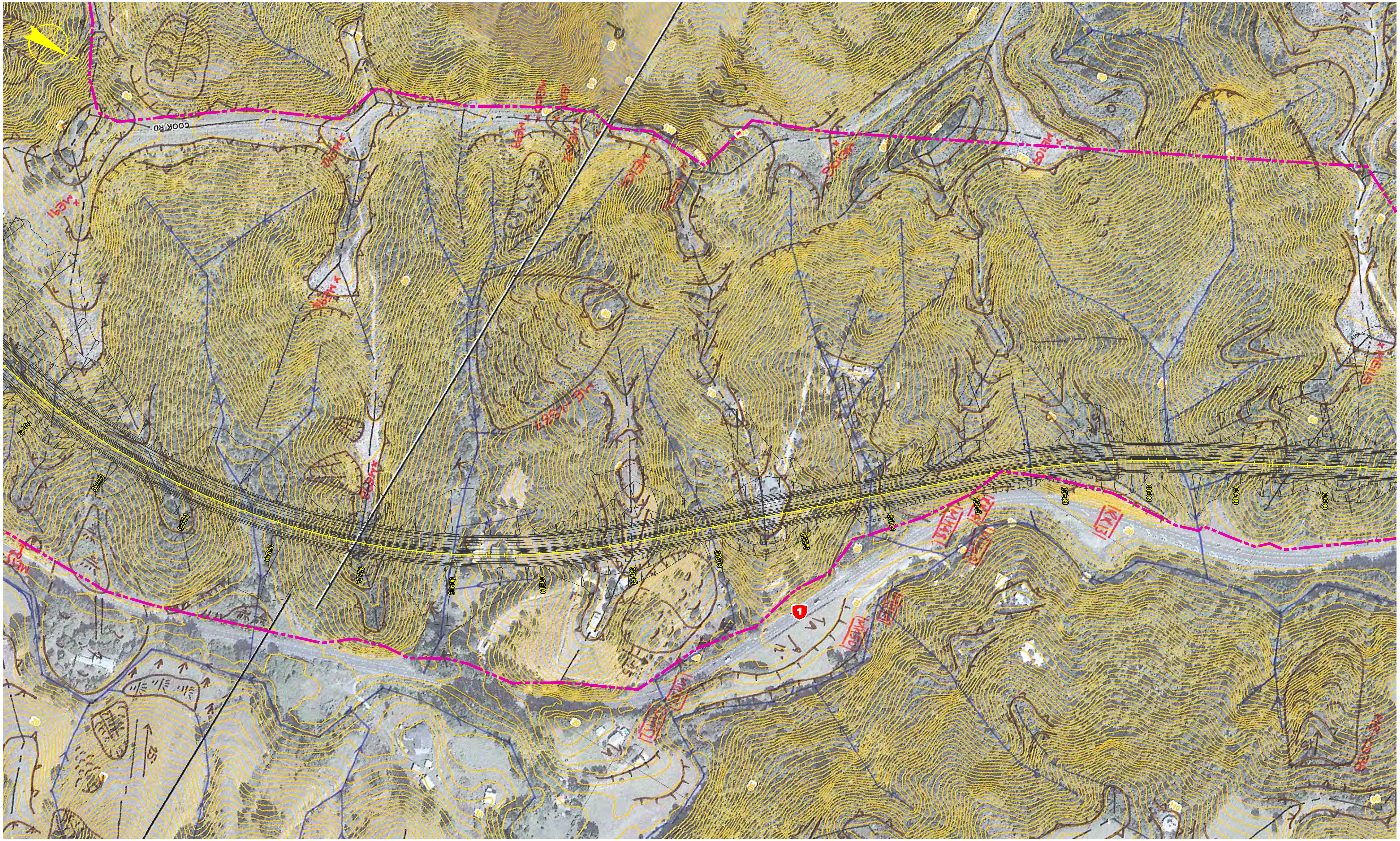
DRAWN	REVIEWED	REVIEWED DISCIPLINE MANAGER	APPROVED ALLIANCE MANAGER
JW	RGK	MRH	TI
DESIGNED RGK	DESIGN REVIEW DJW		

ENGINEERING GEOLOGICAL APPRAISAL MAP
SHEET 3 OF 17

SCALE	CONTRACT No	DRAWING No	AMDT
AS SHOWN	PA3748	GT-103	0

Date: 16/10/2013 Time: 8:41:08 AM

Path: S:\Further North - PAA\300 Design\300.5 Technical\10 GIS\MXD\Z_REPORT_FIGURES\GEOTECHNICAL\GT101_117.mxd



NOTE: FOR GENERAL NOTES AND LEGEND, REFER TO DRAWING GT-001

0 20 40 60 80 100m
SCALE 1:4,000 @ A3 SIZE

AMD	DATE	DESIGN REVIEW	REVD D. MGR	APPD A. MGR	PURPOSE OF ISSUE / AMENDMENT
0	30/08/13	DJW	MRH	TI	ISSUE FOR NOR / CONSENT

FURTHER NORTH

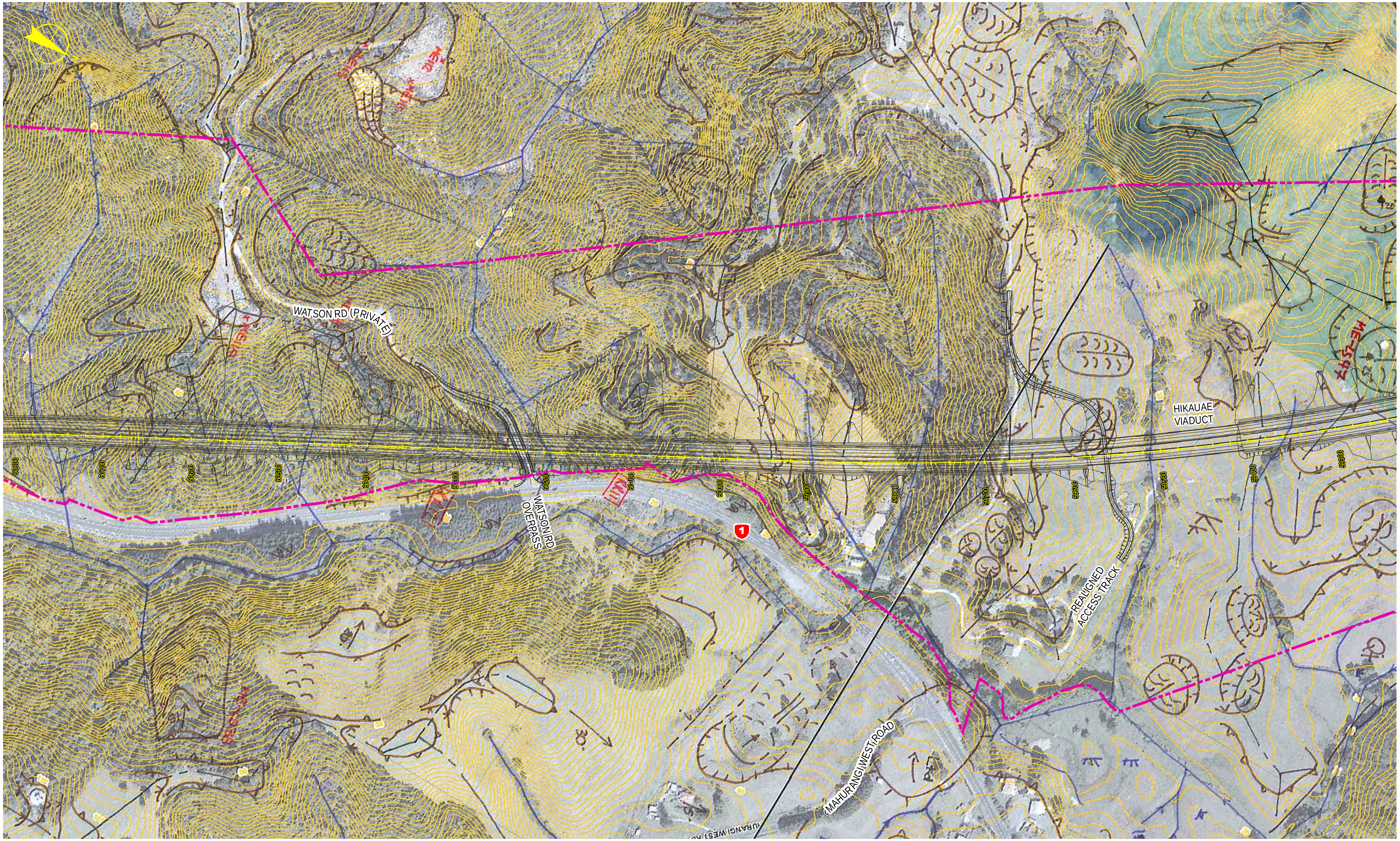
DISCLAIMER
The information shown on this drawing is solely for the purposes of supporting RMA applications for statutory approvals.
All information shown is subject to review for compliance with approved consents and the outcomes of final design.

ARA TŪHONO - PŪHOI TO WELLSFORD
PŪHOI TO WARKWORTH - FOR RMA APPROVALS

DRAWN	REVIEWED	REVIEWED DISCIPLINE MANAGER	APPROVED ALLIANCE MANAGER
JW	RGK	MRH	TI
DESIGNED: RGK	DESIGN REVIEW: DJW		

ENGINEERING GEOLOGICAL APPRAISAL MAP
SHEET 4 OF 17

SCALE	CONTRACT No	DRAWING No	AMDT
AS SHOWN	PA3748	GT-104	0



NOTE: FOR GENERAL NOTES AND LEGEND, REFER TO DRAWING GT-001

0 20 40 60 80 100m
SCALE 1:4,000 @ A3 SIZE

AMD	DATE	DESIGN REVIEW	REVD D. MGR	APPD A. MGR	PURPOSE OF ISSUE / AMENDMENT
0	30/08/13	DJW	MRH	TI	ISSUE FOR NOR / CONSENT

DISCLAIMER
The information shown on this drawing is solely for the purposes of supporting RMA applications for statutory approvals.
All information shown is subject to review for compliance with approved consents and the outcomes of final design.

ARA TŪHONO - PŪHOI TO WELLSFORD

PŪHOI TO WARKWORTH - FOR RMA APPROVALS

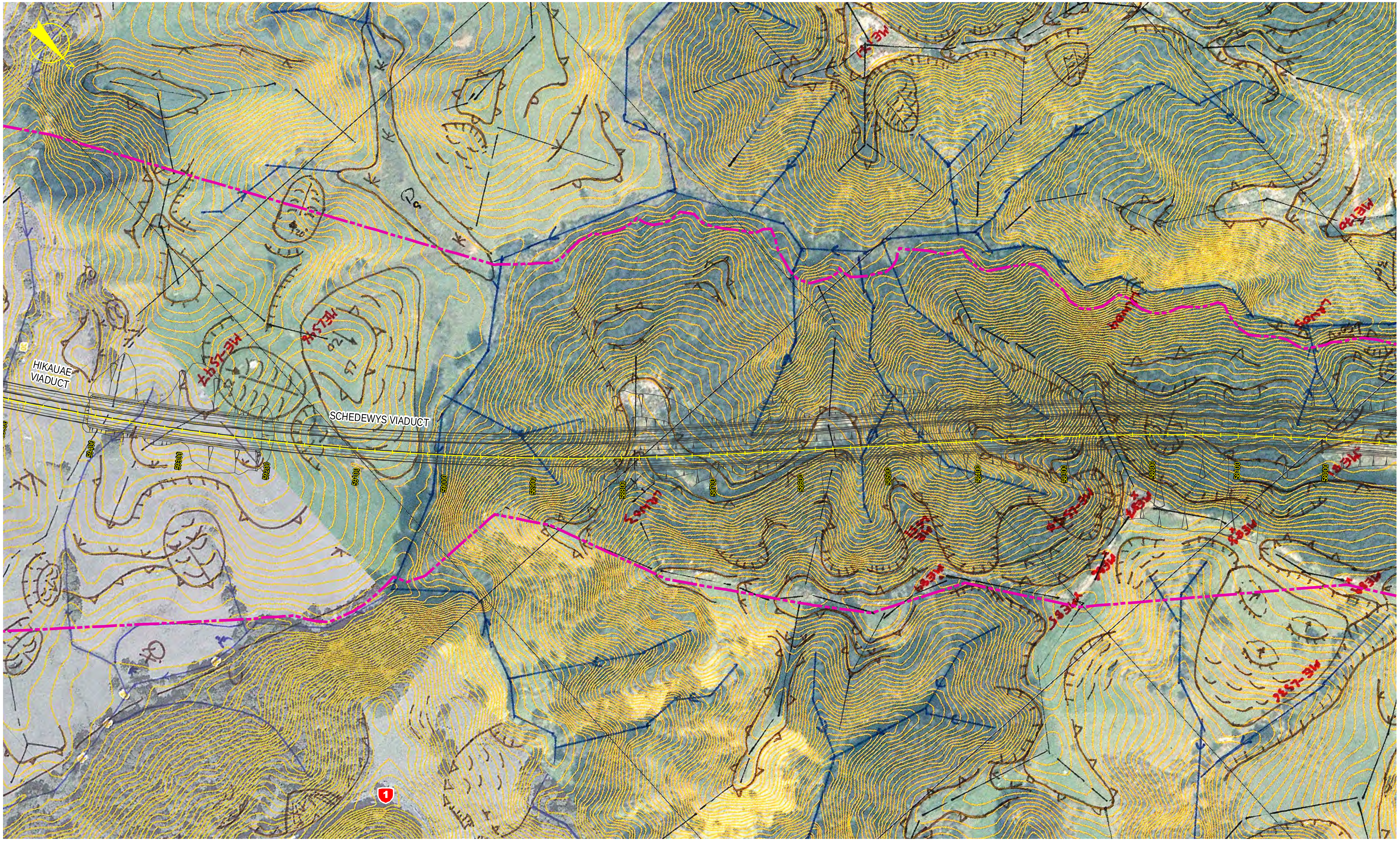
DRAWN	REVIEWED	REVIEWED DISCIPLINE MANAGER	APPROVED ALLIANCE MANAGER
JW	RGK	MRH	TI
DESIGNED: RGK	DESIGN REVIEW: DJW		

ENGINEERING GEOLOGICAL APPRAISAL MAP
SHEET 5 OF 17

SCALE	CONTRACT No	DRAWING No	AMDT
AS SHOWN	PA3748	GT-105	0

Path: S:\Further North - PAA\300 Design\300.5 Technical\10 GIS\MXD\Z_REPORT_FIGURES\GEOTECHNICAL\GT101_117.mxd

Date: 16/10/2013 Time: 8:42:08 AM



NOTE: FOR GENERAL NOTES AND LEGEND, REFER TO DRAWING GT-001

0 20 40 60 80 100m
SCALE 1:4,000 @ A3 SIZE

AMD	DATE	DESIGN REVIEW	REVD D. MGR	APPD A. MGR	PURPOSE OF ISSUE / AMENDMENT
0	30/08/13	DJW	MRH	TI	ISSUE FOR NOR / CONSENT

FURTHER NORTH

DISCLAIMER

The information shown on this drawing is solely for the purposes of supporting RMA applications for statutory approvals. All information shown is subject to review for compliance with approved consents and the outcomes of final design.

ARA TŪHONO - PŪHOI TO WELLSFORD

PŪHOI TO WARKWORTH - FOR RMA APPROVALS

DRAWN	REVIEWED	REVIEWED DISCIPLINE MANAGER	APPROVED ALLIANCE MANAGER
JW	RGK	MRH	TI
DESIGNED	DESIGN REVIEW		
RGK	DJW		

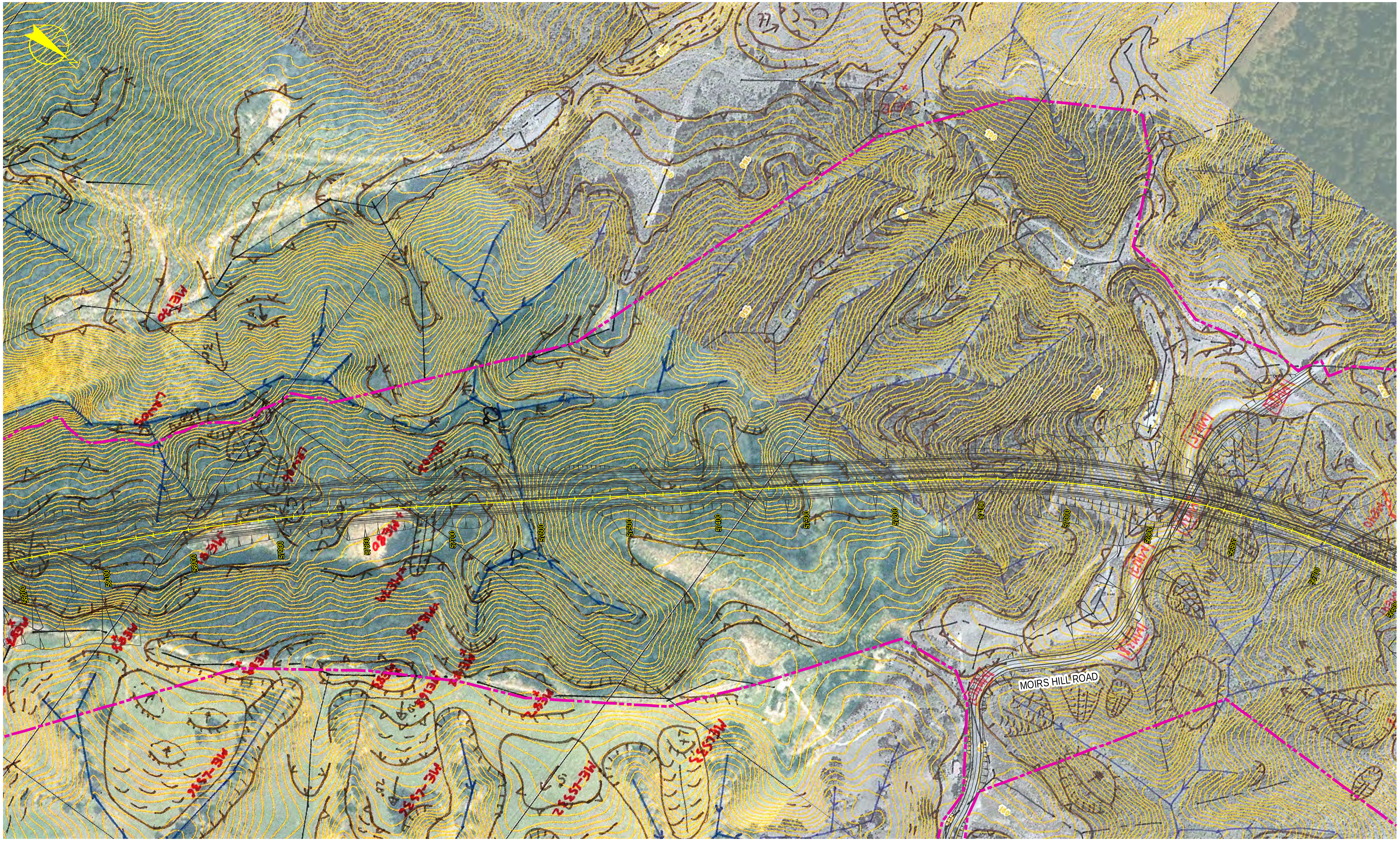
ENGINEERING GEOLOGICAL APPRAISAL MAP
SHEET 6 OF 17

SCALE	CONTRACT No	DRAWING No	AMDT
AS SHOWN	PA3748	GT-106	0

Date: 18/10/2013 Time: 8:42:44 AM

Path: S:\Further North - PAA\300 Design\300.5 Technical\10 GISMXD\Z_REPORT_FIGURES\GEOTECHNICAL\GT101_117.mxd

Date: 16/10/2013 Time: 8:43:37 AM



NOTE: FOR GENERAL NOTES AND LEGEND, REFER TO DRAWING GT-001

0 20 40 60 80 100m

SCALE 1:4,000 @ A3 SIZE

AMD	DATE	DESIGN REVIEW	REVD D. MGR	APPD A. MGR	PURPOSE OF ISSUE / AMENDMENT
0	30/08/13	DJW	MRH	TI	ISSUE FOR NOR / CONSENT

FURTHER NORTH

DISCLAIMER

The information shown on this drawing is solely for the purposes of supporting RMA applications for statutory approvals. All information shown is subject to review for compliance with approved consents and the outcomes of final design.

ARA TŪHONO - PŪHOI TO WELLSFORD

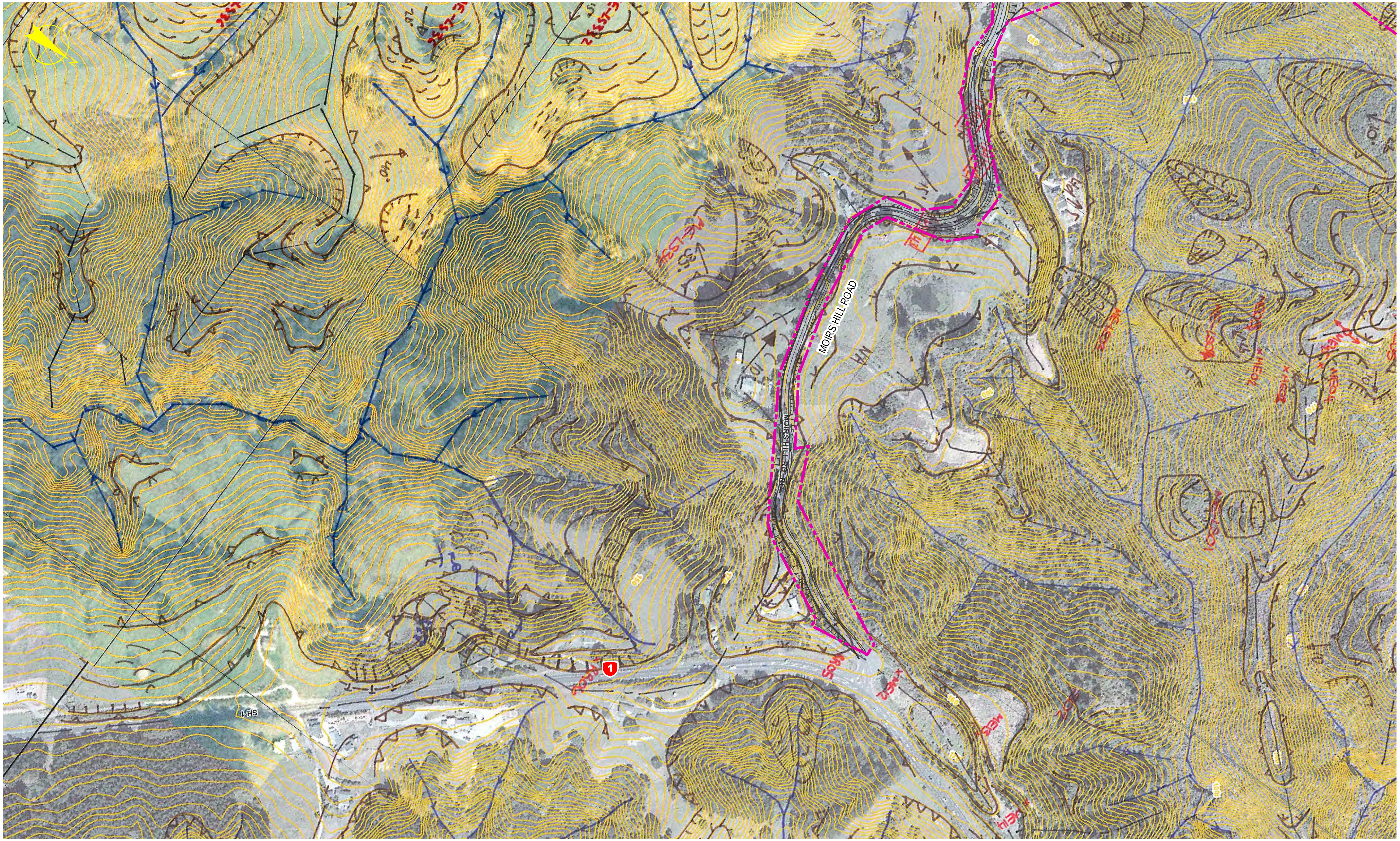
PŪHOI TO WARKWORTH - FOR RMA APPROVALS

DRAWN	REVIEWED	REVIEWED DISCIPLINE MANAGER	APPROVED ALLIANCE MANAGER
JW	RGK	MRH	TI
DESIGNED: RGK	DESIGN REVIEW: DJW		

ENGINEERING GEOLOGICAL APPRAISAL MAP
SHEET 7 OF 17

SCALE	CONTRACT No	DRAWING No	AMDT
AS SHOWN	PA3748	GT-107	0

Path: S:\Further North - PAA\300 Design\300.5 Technical\10 GIS\MXD\Z_REPORT_FIGURES\GEOTECHNICAL\GT101_117.mxd



NOTE: FOR GENERAL NOTES AND LEGEND, REFER TO DRAWING GT-001

0 20 40 60 80 100m
SCALE 1:4,000 @ A3 SIZE

AMD	DATE	DESIGN REVIEW	REVD D. MGR	APPD A. MGR	PURPOSE OF ISSUE / AMENDMENT
0	30/08/13	DJW	MRH	TI	ISSUE FOR NOR / CONSENT

FURTHER NORTH

DISCLAIMER
The information shown on this drawing is solely for the purposes of supporting RMA applications for statutory approvals.
All information shown is subject to review for compliance with approved consents and the outcomes of final design.

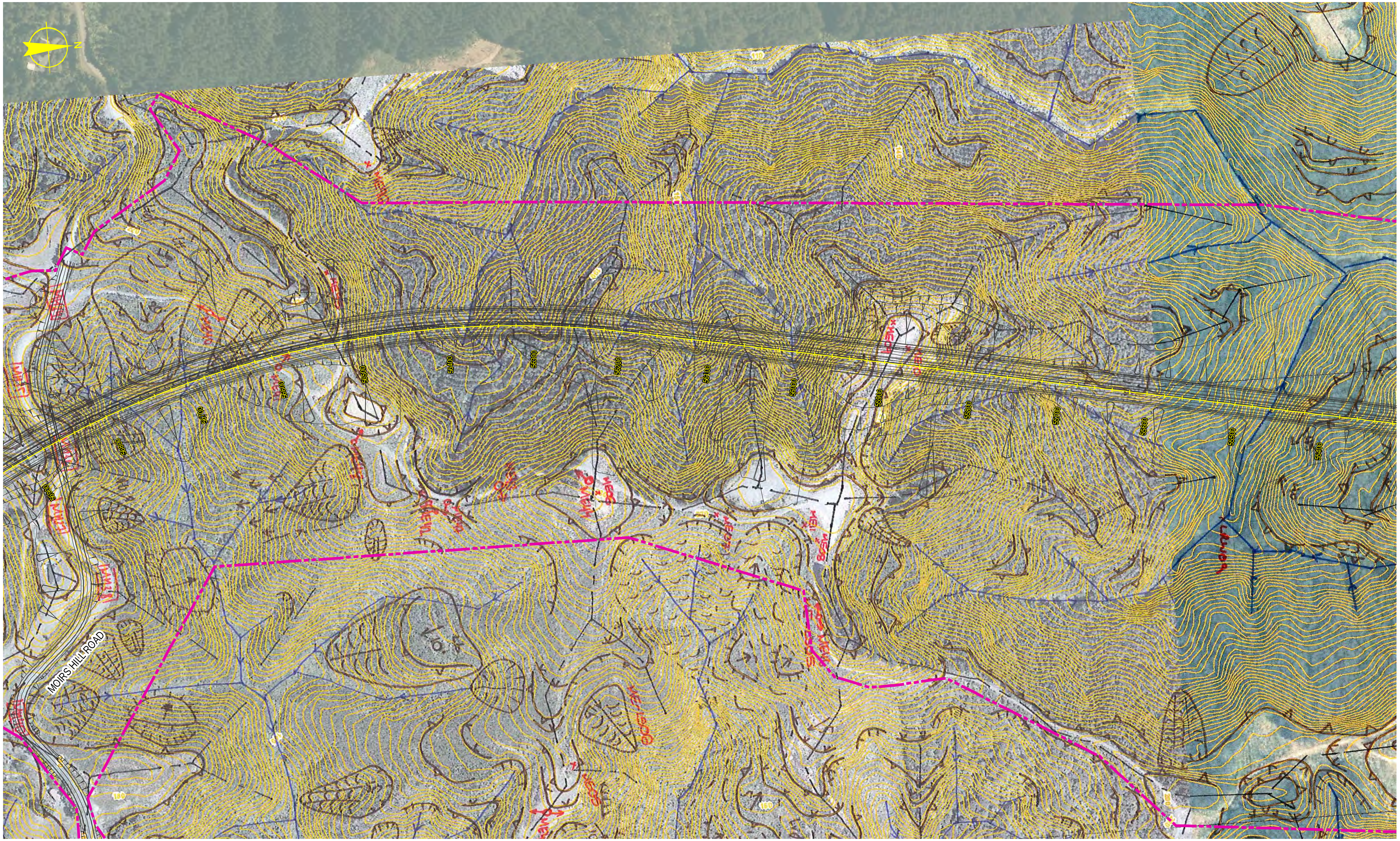
ARA TŪHONO - PŪHOI TO WELLSFORD
PŪHOI TO WARKWORTH - FOR RMA APPROVALS

DRAWN	REVIEWED	REVIEWED DISCIPLINE MANAGER	APPROVED ALLIANCE MANAGER
JW	RGK	MRH	TI
DESIGNED: RGK	DESIGN REVIEW: DJW		

ENGINEERING GEOLOGICAL APPRAISAL MAP
SHEET 8 OF 17

SCALE	CONTRACT No	DRAWING No	AMDT
AS SHOWN	PA3748	GT-108	0

Date: 16/10/2013 Time: 8:44:16 AM
Path: S:\Further North - PAA\300 Design\300.5 Technical\10 GIS\MXD\Z_REPORT_FIGURES\GEOTECHNICAL\GT101_117.mxd



NOTE: FOR GENERAL NOTES AND LEGEND, REFER TO DRAWING GT-001

0 20 40 60 80 100m

SCALE 1:4,000 @ A3 SIZE

AMD	DATE	DESIGN REVIEW	REVD D. MGR	APPD A. MGR	PURPOSE OF ISSUE / AMENDMENT
0	30/08/13	DJW	MRH	TI	ISSUE FOR NOR / CONSENT

DISCLAIMER

The information shown on this drawing is solely for the purposes of supporting RMA applications for statutory approvals. All information shown is subject to review for compliance with approved consents and the outcomes of final design.

ARA TŪHONO - PŪHOI TO WELLSFORD

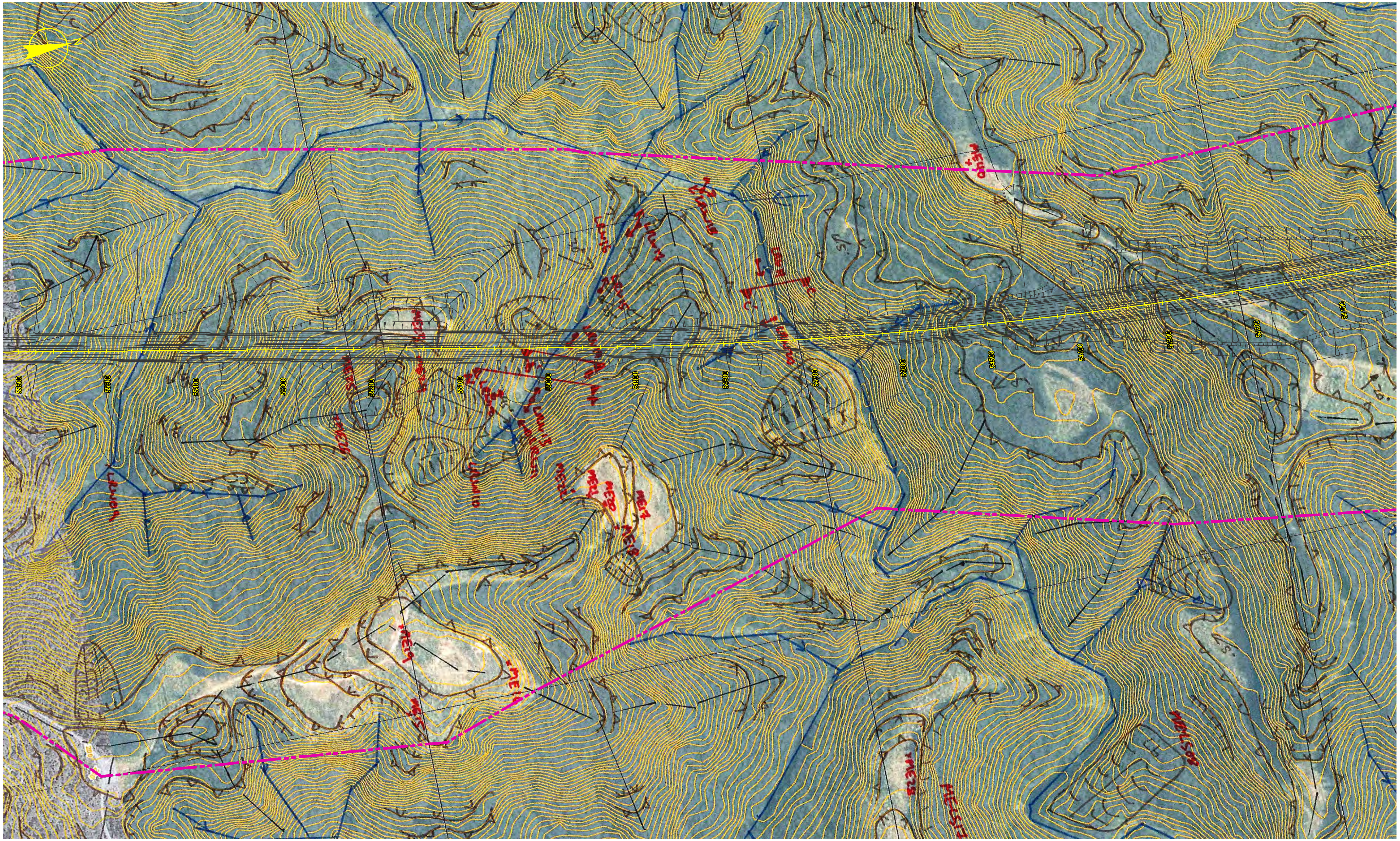
PŪHOI TO WARKWORTH - FOR RMA APPROVALS

DRAWN	REVIEWED	REVIEWED DISCIPLINE MANAGER	APPROVED ALLIANCE MANAGER
JW	RGK	MRH	TI
DESIGNED: RGK	DESIGN REVIEW: DJW		

ENGINEERING GEOLOGICAL APPRAISAL MAP

SHEET 9 OF 17

SCALE	CONTRACT No	DRAWING No	AMDT
AS SHOWN	PA3748	GT-109	0



NOTE: FOR GENERAL NOTES AND LEGEND, REFER TO DRAWING GT-001

0 20 40 60 80 100m
SCALE 1:4,000 @ A3 SIZE

AMD	DATE	DESIGN REVIEW	REVD D. MGR	APPD A. MGR	PURPOSE OF ISSUE / AMENDMENT
0	30/08/13	DJW	MRH	TI	ISSUE FOR NOR / CONSENT

FURTHER NORTH

DISCLAIMER
The information shown on this drawing is solely for the purposes of supporting RMA applications for statutory approvals.
All information shown is subject to review for compliance with approved consents and the outcomes of final design.

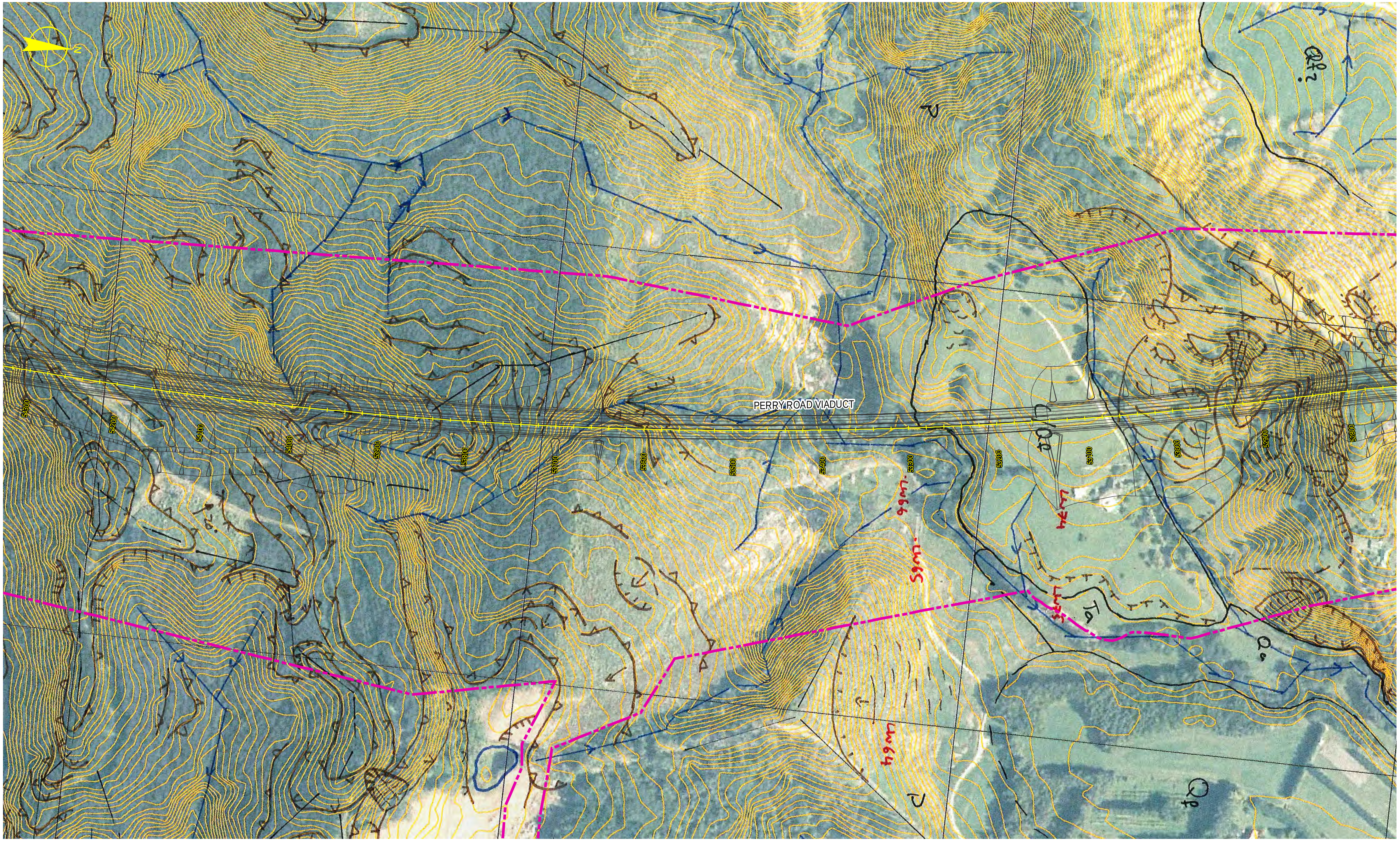
ARA TŪHONO - PŪHOI TO WELLSFORD
PŪHOI TO WARKWORTH - FOR RMA APPROVALS

DRAWN	REVIEWED	REVIEWED DISCIPLINE MANAGER	APPROVED ALLIANCE MANAGER
JW	RGK	MRH	TI
DESIGNED: RGK	DESIGN REVIEW: DJW		

ENGINEERING GEOLOGICAL APPRAISAL MAP
SHEET 10 OF 17

SCALE	CONTRACT No	DRAWING No	AMDT
AS SHOWN	PA3748	GT-110	0

Path: S:\Further North - PAA\300 Design\300.5 Technical\10 GIS\MXD\Z_REPORT_FIGURES\GEOTECHNICAL\GT101_117.mxd
Date: 16/10/2013 Time: 8:45:21 AM



NOTE: FOR GENERAL NOTES AND LEGEND, REFER TO DRAWING GT-001

0 20 40 60 80 100m

SCALE 1:4,000 @ A3 SIZE

AMD	DATE	DESIGN REVIEW	REVD D. MGR	APPD A. MGR	PURPOSE OF ISSUE / AMENDMENT
0	30/08/13	DJW	MRH	TI	ISSUE FOR NOR / CONSENT

FURTHER NORTH

DISCLAIMER

The information shown on this drawing is solely for the purposes of supporting RMA applications for statutory approvals. All information shown is subject to review for compliance with approved consents and the outcomes of final design.

ARA TŪHONO - PŪHOI TO WELLSFORD

PŪHOI TO WARKWORTH - FOR RMA APPROVALS

DRAWN	REVIEWED	REVIEWED DISCIPLINE MANAGER	APPROVED ALLIANCE MANAGER
JW	RGK	MRH	TI
DESIGNED: RGK	DESIGN REVIEW: DJW		

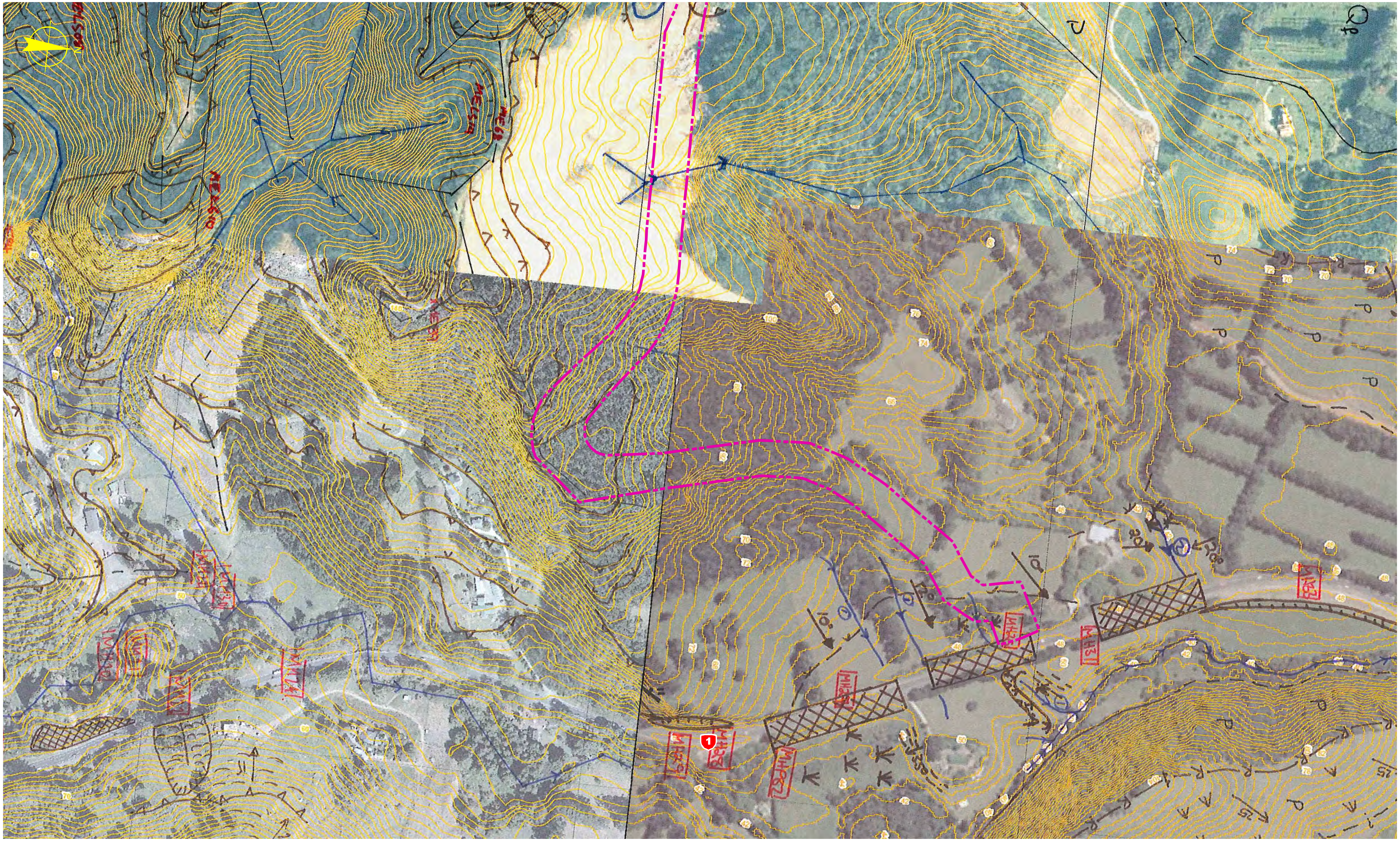
ENGINEERING GEOLOGICAL APPRAISAL MAP

SHEET 11 OF 17

SCALE	CONTRACT No.	DRAWING No.	AMDT
AS SHOWN	PA3748	GT-111	0

Date: 16/10/2013 Time: 8:46:07 AM

Path: S:\Further North - PAA\300 Design\300.5 Technical\10 GIS\MXD\Z_REPORT_FIGURES\GEOTECHNICAL\GT101_117.mxd



NOTE: FOR GENERAL NOTES AND LEGEND, REFER TO DRAWING GT-001

0 20 40 60 80 100m
SCALE 1:4,000 @ A3 SIZE

AMD	DATE	DESIGN REVIEW	REVD D. MGR	APPD A. MGR	PURPOSE OF ISSUE / AMENDMENT
0	30/08/13	DJW	MRH	TI	ISSUE FOR NOR / CONSENT

FURTHER NORTH

DISCLAIMER
The information shown on this drawing is solely for the purposes of supporting RMA applications for statutory approvals. All information shown is subject to review for compliance with approved consents and the outcomes of final design.

ARA TŪHONO - PŪHOI TO WELLSFORD
PŪHOI TO WARKWORTH - FOR RMA APPROVALS

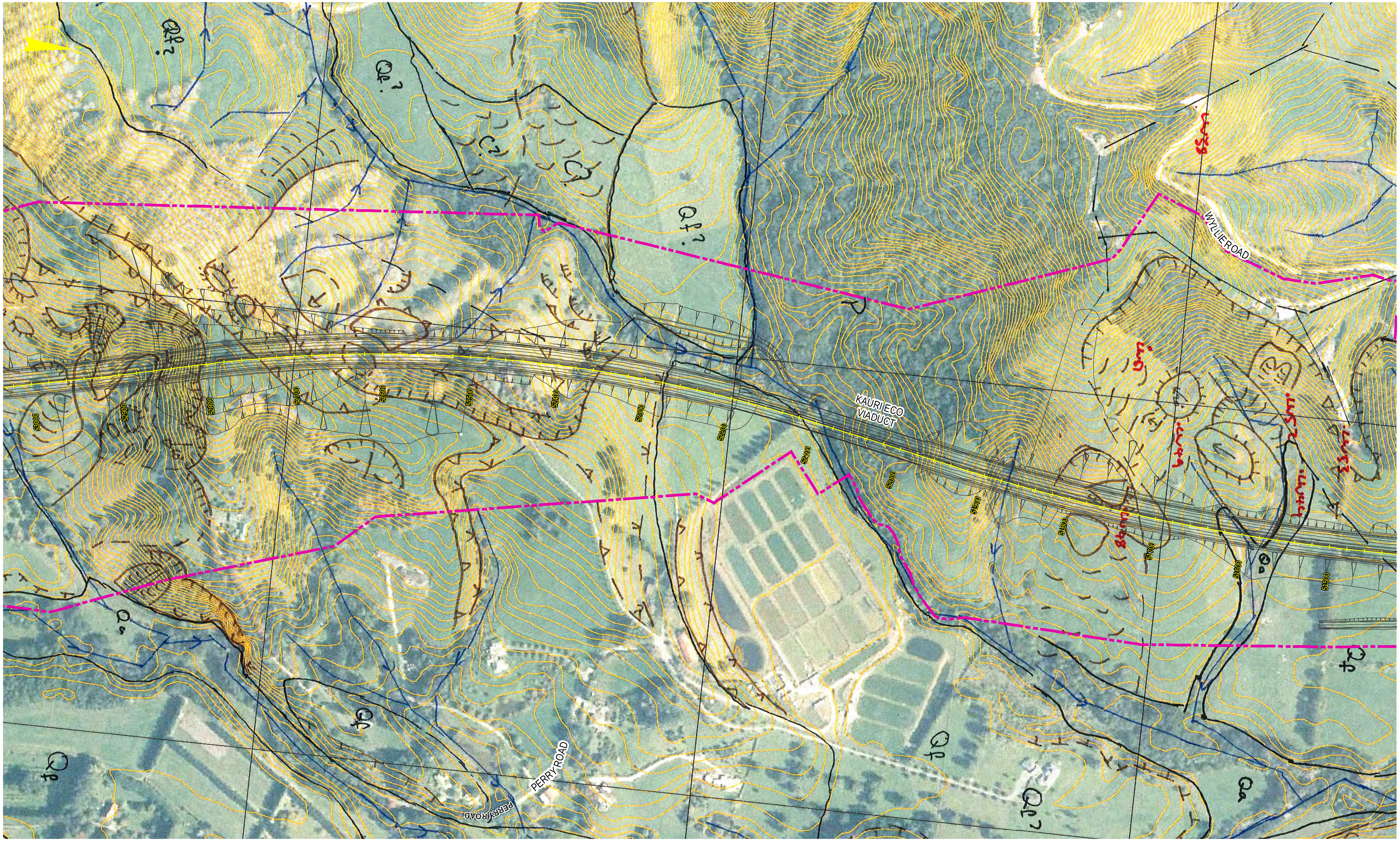
DRAWN	REVIEWED	REVIEWED DISCIPLINE MANAGER	APPROVED ALLIANCE MANAGER
JW	RGK	MRH	TI
DESIGNED RGK	DESIGN REVIEW DJW		

ENGINEERING GEOLOGICAL APPRAISAL MAP
SHEET 12 OF 17

SCALE	CONTRACT No	DRAWING No	AMDT
AS SHOWN	PA3748	GT-112	0

Date: 18/10/2013 Time: 8:46:34 AM
Path: S:\Further North - PAA\300 Design\300.5 Technical\10 GIS\MXD\Z_REPORT_FIGURES\GEOTECHNICAL\GT101_117.mxd

Date: 16/10/2013 Time: 8:47:22 AM



NOTE: FOR GENERAL NOTES AND LEGEND, REFER TO DRAWING GT-001

0 20 40 60 80 100m
SCALE 1:4,000 @ A3 SIZE

AMD	DATE	DESIGN REVIEW	REVD D. MGR	APPD A. MGR	PURPOSE OF ISSUE / AMENDMENT
0	30/08/13	DJW	MRH	TI	ISSUE FOR NOR / CONSENT

FURTHER NORTH

DISCLAIMER
The information shown on this drawing is solely for the purposes of supporting RMA applications for statutory approvals.
All information shown is subject to review for compliance with approved consents and the outcomes of final design.

ARA TŪHONO - PŪHOI TO WELLSFORD

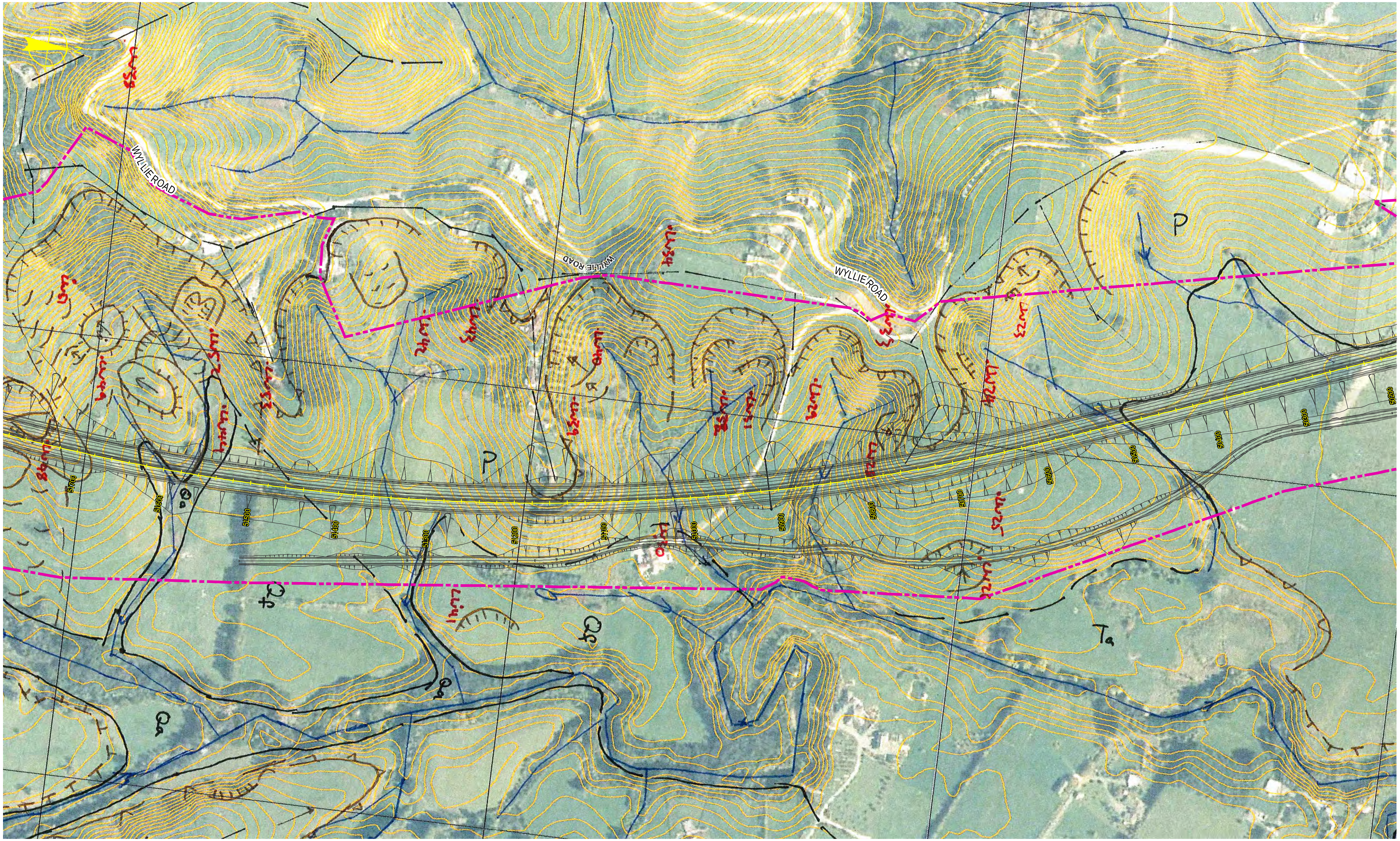
PŪHOI TO WARKWORTH - FOR RMA APPROVALS

DRAWN	REVIEWED	REVIEWED DISCIPLINE MANAGER	APPROVED ALLIANCE MANAGER
JW	RGK	MRH	TI
DESIGNED RGK	DESIGN REVIEW DJW		

ENGINEERING GEOLOGICAL APPRAISAL MAP
SHEET 13 OF 17

SCALE	CONTRACT No	DRAWING No	AMDT
AS SHOWN	PA3748	GT-113	0

Path: S:\Further North - PAA\300 Design\300.5 Technical\10 GIS\MXD\Z_REPORT_FIGURES\GEOTECHNICAL\GT101_117.mxd



NOTE: FOR GENERAL NOTES AND LEGEND, REFER TO DRAWING GT-001

0 20 40 60 80 100m
SCALE 1:4,000 @ A3 SIZE

AMD	DATE	DESIGN REVIEW	REVD D. MGR	APPD A. MGR	PURPOSE OF ISSUE / AMENDMENT
0	30/08/13	DJW	MRH	TI	ISSUE FOR NOR / CONSENT

FURTHER NORTH

DISCLAIMER
The information shown on this drawing is solely for the purposes of supporting RMA applications for statutory approvals.
All information shown is subject to review for compliance with approved consents and the outcomes of final design.

ARA TŪHONO - PŪHOI TO WELLSFORD

PŪHOI TO WARKWORTH - FOR RMA APPROVALS

DRAWN	REVIEWED	REVIEWED DISCIPLINE MANAGER	APPROVED ALLIANCE MANAGER
JW	RGK	MRH	TI
DESIGNED	DESIGN REVIEW		
RGK	DJW		

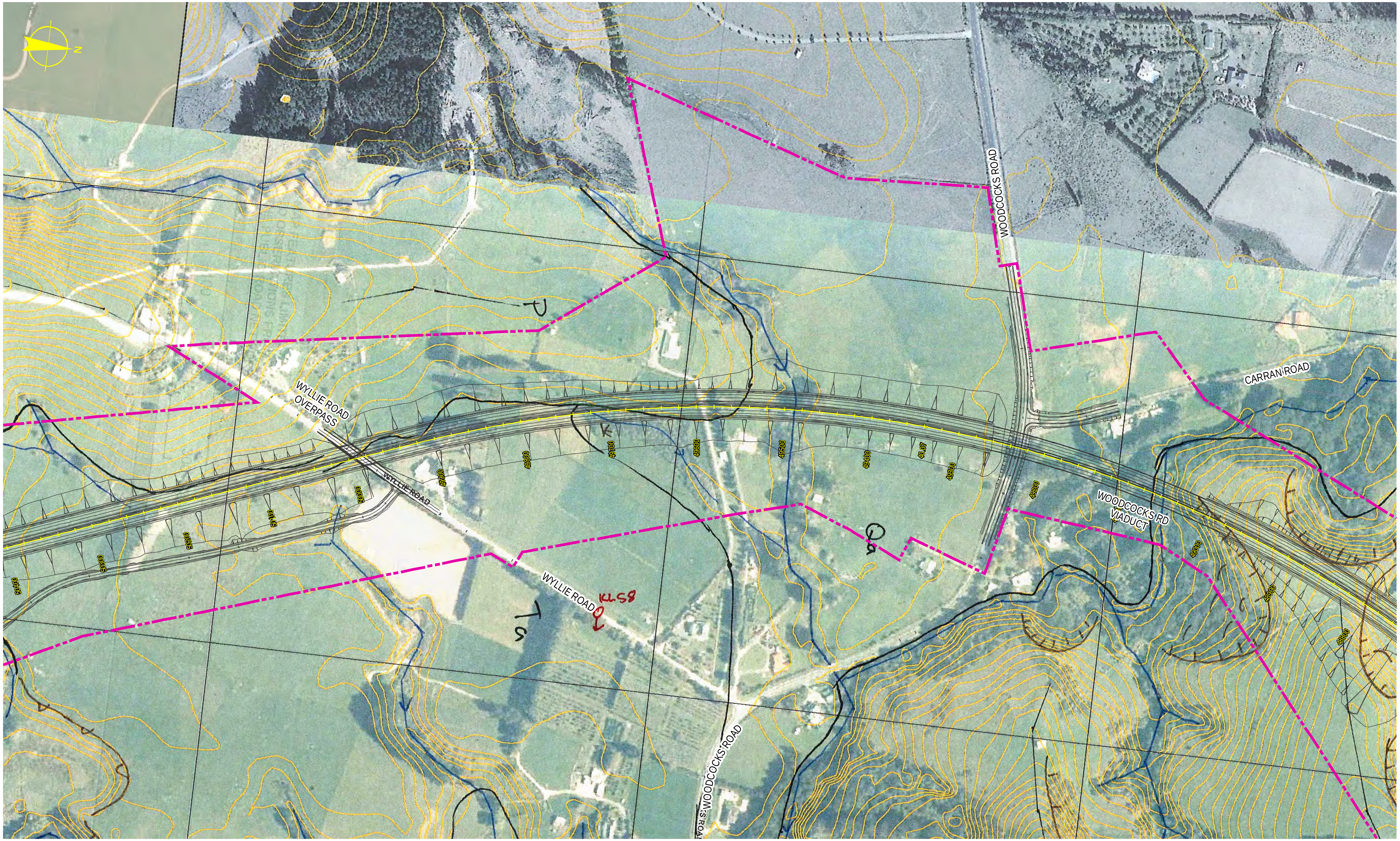
ENGINEERING GEOLOGICAL APPRAISAL MAP
SHEET 14 OF 17

SCALE	CONTRACT No	DRAWING No	AMDT
AS SHOWN	PA3748	GT-114	0

Date: 16/10/2013 Time: 8:48:10 AM

Path: S:\Further North - PAA\300 Design\300.5 Technical\10 GIS\MXD\Z_REPORT_FIGURES\GEOTECHNICAL\GT101_117.mxd

Date: 16/10/2013 Time: 8:48:52 AM



NOTE: FOR GENERAL NOTES AND LEGEND, REFER TO DRAWING GT-001

0 20 40 60 80 100m
SCALE 1:4,000 @ A3 SIZE

AMD	DATE	DESIGN REVIEW	REVD D. MGR	APPD A. MGR	PURPOSE OF ISSUE / AMENDMENT
0	30/08/13	DJW	MRH	TI	ISSUE FOR NOR / CONSENT

FURTHER NORTH

DISCLAIMER
The information shown on this drawing is solely for the purposes of supporting RMA applications for statutory approvals. All information shown is subject to review for compliance with approved consents and the outcomes of final design.

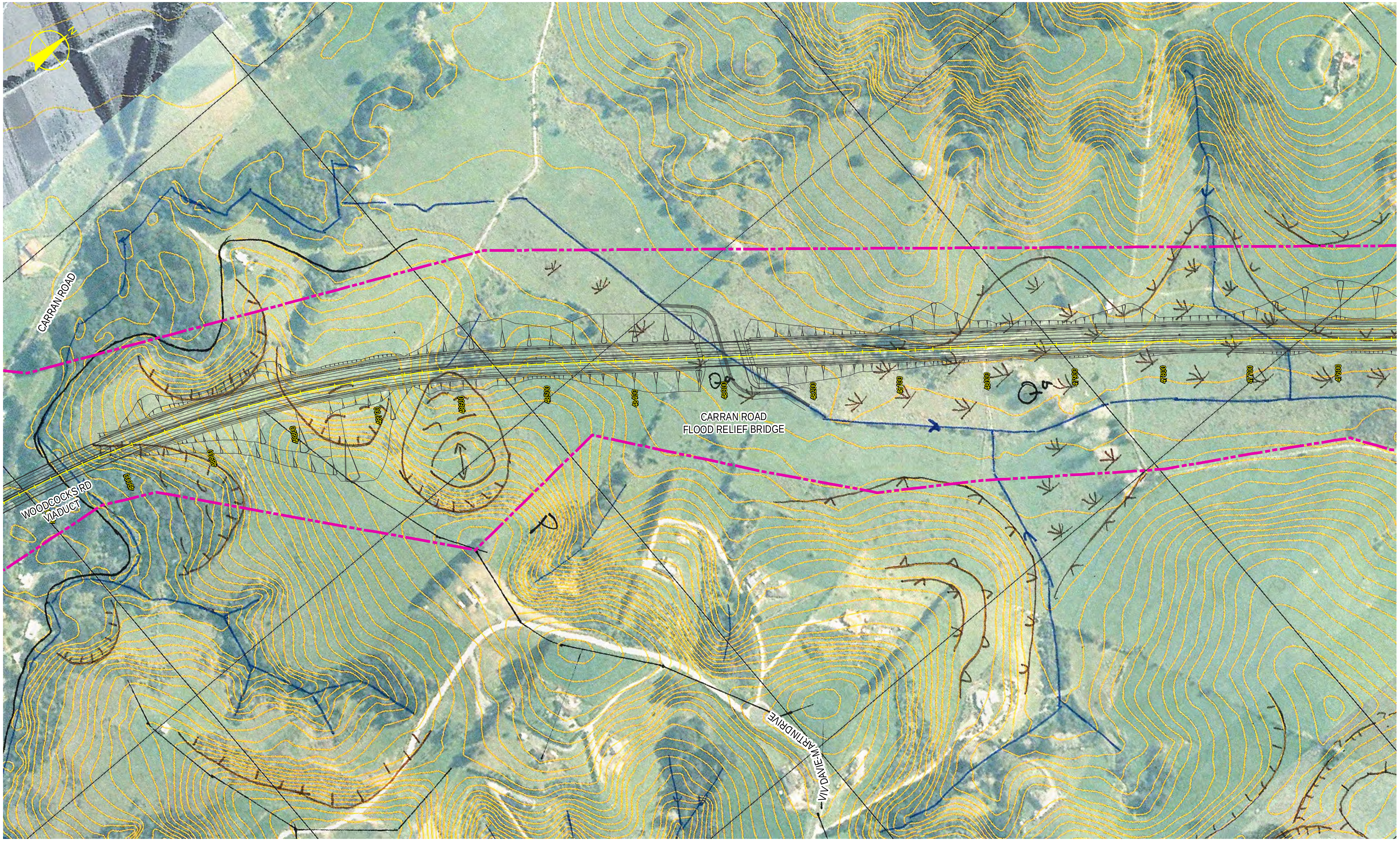
ARA TŪHONO - PŪHOI TO WELLSFORD
PŪHOI TO WARKWORTH - FOR RMA APPROVALS

DRAWN	REVIEWED	REVIEWED DISCIPLINE MANAGER	APPROVED ALLIANCE MANAGER
JW	RGK	MRH	TI
DESIGNED: RGK	DESIGN REVIEW: DJW		

ENGINEERING GEOLOGICAL APPRAISAL MAP
SHEET 15 OF 17

SCALE	CONTRACT No	DRAWING No	AMDT
AS SHOWN	PA3748	GT-115	0

Path: S:\Further North - PAA\300 Design\300.5 Technical\10 GIS\MXD\Z_REPORT_FIGURES\GEOTECHNICAL\GT101_117.mxd



NOTE: FOR GENERAL NOTES AND LEGEND, REFER TO DRAWING GT-001

0 20 40 60 80 100m
SCALE 1:4,000 @ A3 SIZE

AMD	DATE	DESIGN REVIEW	REVD D. MGR	APPD A. MGR	PURPOSE OF ISSUE / AMENDMENT
0	30/08/13	DJW	MRH	TI	ISSUE FOR NOR / CONSENT

FURTHER NORTH

DISCLAIMER
The information shown on this drawing is solely for the purposes of supporting RMA applications for statutory approvals.
All information shown is subject to review for compliance with approved consents and the outcomes of final design.

ARA TŪHONO - PŪHOI TO WELLSFORD

PŪHOI TO WARKWORTH - FOR RMA APPROVALS

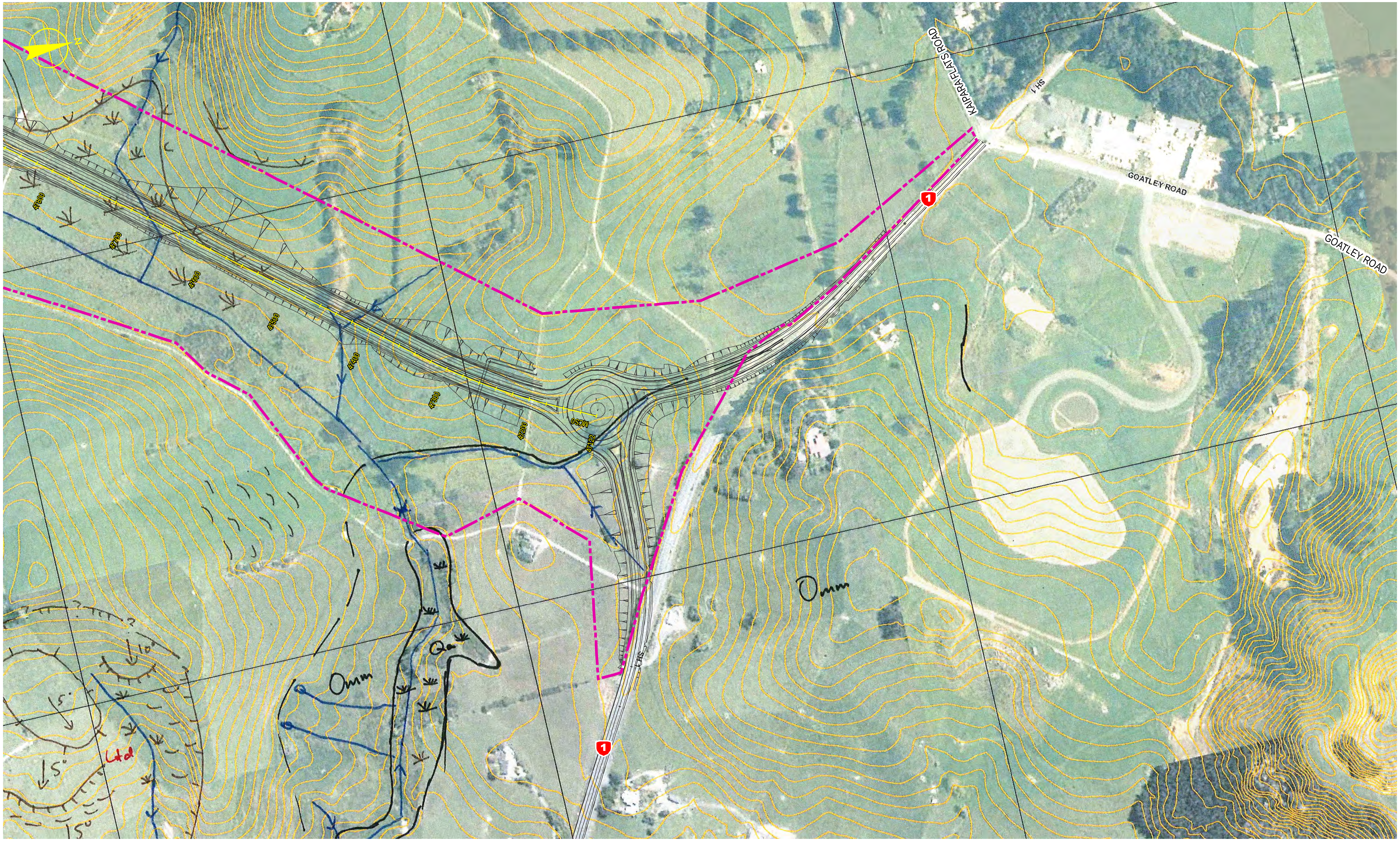
DRAWN	REVIEWED	REVIEWED DISCIPLINE MANAGER	APPROVED ALLIANCE MANAGER
JW	RGK	MRH	TI
DESIGNED: RGK	DESIGN REVIEW: DJW		

ENGINEERING GEOLOGICAL APPRAISAL MAP SHEET 16 OF 17

SCALE	CONTRACT No	DRAWING No	AMDT
AS SHOWN	PA3748	GT-116	0

Date: 16/10/2013 Time: 8:49:53 AM
Path: S:\Further North - PAA\300 Design\300.5 Technical\10 GIS\MXD\Z_REPORT_FIGURES\GEOTECHNICAL\GT101_117.mxd

Date: 16/10/2013 Time: 8:50:34 AM



NOTE: FOR GENERAL NOTES AND LEGEND, REFER TO DRAWING GT-001

0 20 40 60 80 100m
SCALE 1:4,000 @ A3 SIZE

AMD	DATE	DESIGN REVIEW	REVD D. MGR	APPD A. MGR	PURPOSE OF ISSUE / AMENDMENT
0	30/08/13	DJW	MRH	TI	ISSUE FOR NOR / CONSENT

FURTHER NORTH

DISCLAIMER
The information shown on this drawing is solely for the purposes of supporting RMA applications for statutory approvals. All information shown is subject to review for compliance with approved consents and the outcomes of final design.

ARA TŪHONO - PŪHOI TO WELLSFORD
PŪHOI TO WARKWORTH - FOR RMA APPROVALS

DRAWN	REVIEWED	REVIEWED DISCIPLINE MANAGER	APPROVED ALLIANCE MANAGER
JW	RGK	MRH	TI
DESIGNED: RGK	DESIGN REVIEW: DJW		

ENGINEERING GEOLOGICAL APPRAISAL MAP
SHEET 17 OF 17

SCALE	CONTRACT No.	DRAWING No.	AMDT
AS SHOWN	PA3748	GT-117	0

Path: S:\Further North - PAA\300 Design\300.5 Technical\10 GIS\MXD\Z_REPORT_FIGURES\GEOTECHNICAL\GT101_117.mxd

Appendix E. Geological Longitudinal Section

GT-151	Geological Longitudinal Section - Sheet 1 of 11
GT-152	Geological Longitudinal Section - Sheet 2 of 11
GT-153	Geological Longitudinal Section - Sheet 3 of 11
GT-154	Geological Longitudinal Section - Sheet 4 of 11
GT-155	Geological Longitudinal Section - Sheet 5 of 11
GT-156	Geological Longitudinal Section - Sheet 6 of 11
GT-157	Geological Longitudinal Section - Sheet 7 of 11
GT-158	Geological Longitudinal Section - Sheet 8 of 11
GT-159	Geological Longitudinal Section - Sheet 9 of 11
GT-160	Geological Longitudinal Section - Sheet 10 of 11
GT-161	Geological Longitudinal Section - Sheet 11 of 11

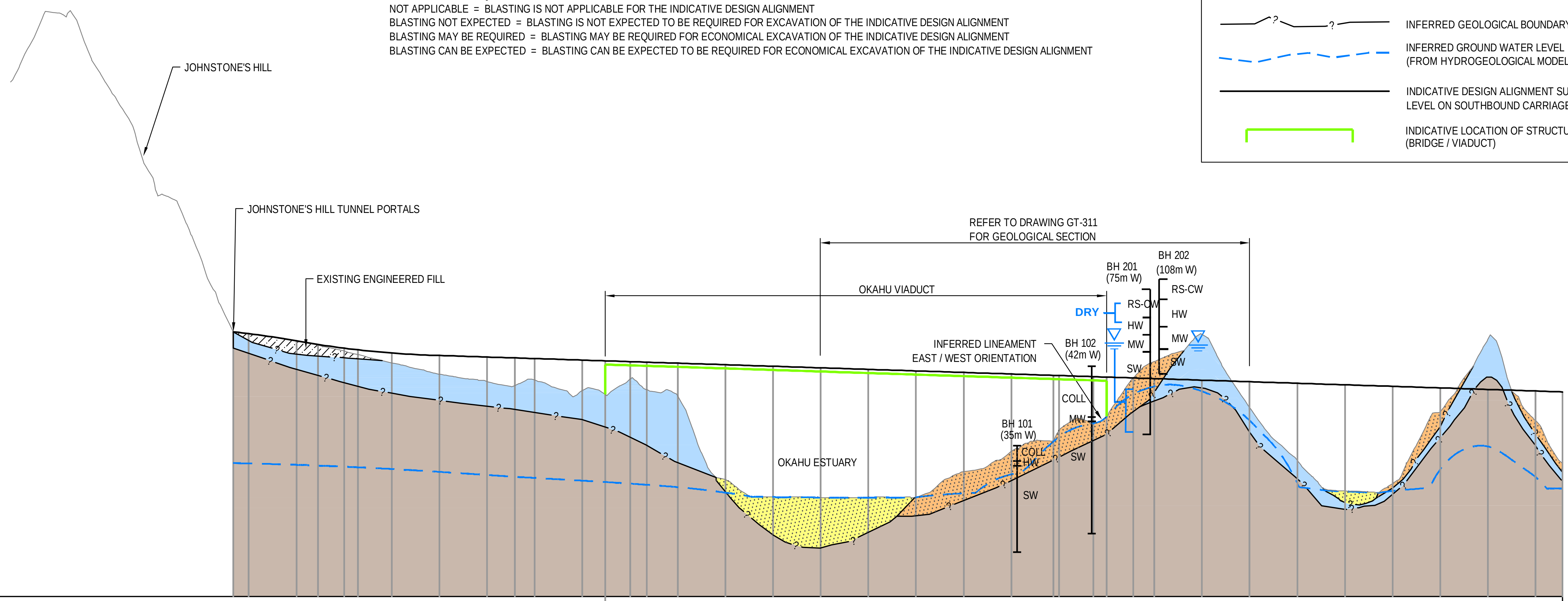
NOTES

1. LOCAL VARIATIONS OR ANOMALIES IN GROUND CONDITIONS CAN OCCUR IN THE NATURAL ENVIRONMENT, PARTICULARLY BETWEEN DISCRETE TEST HOLE LOCATIONS
2. REFER TO DRAWINGS GT-201 TO GT-215 FOR BOREHOLE LOCATIONS
3. VERTICAL EXAGGERATION IS 5:1. GEOLOGICAL BOUNDARIES ARE TO BE REGARDED AS INDICATIVE ONLY
4. BOREHOLE ABBREVIATIONS: RS = RESIDUAL SOIL
   CW = COMPLETELY WEATHERED
   HW = HIGHLY WEATHERED
   MW = MODERATELY WEATHERED
   SW = SLIGHTLY WEATHERED
   UN = UNWEATHERED
   COLL = COLLUVIUM
5. POTENTIAL BLASTING REQUIREMENTS:
   NOT APPLICABLE = BLASTING IS NOT APPLICABLE FOR THE INDICATIVE DESIGN ALIGNMENT
   BLASTING NOT EXPECTED = BLASTING IS NOT EXPECTED TO BE REQUIRED FOR EXCAVATION OF THE INDICATIVE DESIGN ALIGNMENT
   BLASTING MAY BE REQUIRED = BLASTING MAY BE REQUIRED FOR ECONOMICAL EXCAVATION OF THE INDICATIVE DESIGN ALIGNMENT
   BLASTING CAN BE EXPECTED = BLASTING CAN BE EXPECTED TO BE REQUIRED FOR ECONOMICAL EXCAVATION OF THE INDICATIVE DESIGN ALIGNMENT

KEY

- COLLUVIUM
- ALLUVIUM
- SOIL } PAKIRI FORMATION
- ROCK } PAKIRI FORMATION
- MANGAKAHIA COMPLEX (Kk) (NORTHLAND ALLOCHTHON)

BOREHOLE
- (5m W) OFFSET / DIRECTION FROM ROAD
- RS-CW, HW, MW, SW
- MEASURED PIEZOMETRIC READING
- PIEZOMETER - SCREEN INTERVAL
- N≥50 SPT N VALUES ≥50 BELOW THIS DEPTH WHERE SPT CARRIED OUT
- INFERRED GEOLOGICAL BOUNDARY
- INFERRED GROUND WATER LEVEL (FROM HYDROGEOLOGICAL MODEL)
- INDICATIVE DESIGN ALIGNMENT SURFACE LEVEL ON SOUTHBOUND CARRIAGEWAY (MCS0)
- INDICATIVE LOCATION OF STRUCTURE (BRIDGE / VIADUCT)



CHAINAGE	DESIGN SURFACE LEVEL	EXISTING SURFACE LEVEL
65250.000		87.987
65200.000		102.457
65150.000		87.823
65100.000		67.464
65050.000		50.916
65000.000	35.136	35.174
64950.000	33.611	33.614
64927.552		
64900.000	32.095	31.510
64885.552		
64850.000	31.079	29.018
64800.000	30.560	26.633
64750.000	30.236	25.102
64721.042		
64700.000	29.912	25.426
64650.000	29.588	23.191
64624.422		
64600.000	29.264	25.612
64582.422		
64550.000	28.939	22.038
64500.000	28.615	4.474
64450.000	28.291	0.899
64400.000	27.967	0.697
64350.000	27.643	0.772
64300.000	27.319	0.865
64250.000	26.995	6.169
64200.000	26.670	10.430
64155.975		
64150.000	26.346	14.778
64113.975		
64100.000	26.022	17.746
64071.975		
64050.000	25.698	29.289
64000.000	25.374	34.979
63950.000	25.050	19.626
63900.000	24.726	8.521
63850.000	24.402	2.115
63800.000	24.077	3.708
63750.000	23.753	18.737
63700.000	23.429	33.959
63650.000	23.105	16.916

POTENTIAL BLASTING REQUIREMENTS (REFER TO NOTE 5)

Extent	Requirement
65250.000 to 64071.975	NOT APPLICABLE
64071.975 to approx. 63960	BLASTING NOT EXPECTED
approx. 63960 to approx. 63735	NOT APPLICABLE
approx. 63735 to approx. 63670	BLASTING NOT EXPECTED
approx. 63670 to 63650.000	N/A

LONGITUDINAL SECTION - MCS0 (CH 63650 TO CH 65250)

HORIZONTAL SCALE 1:5000 @ A3
VERTICAL SCALE 1:1000 @ A3

HORIZONTAL 1:5,000 (0, 25, 50, 75, 100, 125m)
VERTICAL 1:1,000 (0, 5, 10, 15, 20, 25m)
@ A3 SIZE

AMD	DATE	DESIGN REVIEW	REV'D D. MGR	APP'D A. MGR	PURPOSE OF ISSUE / AMENDMENT
0	30/08/13	DJW	MRH	TI	ISSUED FOR NOR / CONSENT

FURTHER NORTH

DISCLAIMER
The information shown on this drawing is solely for the purposes of supporting RMA applications for statutory approvals. All information shown is subject to review for compliance with approved consents and the outcomes of final design.

ARA TŪHONO - PŪHOI TO WELLSFORD
PŪHOI TO WARKWORTH - FOR RMA APPROVALS

DRAWN	DRAFTING CHECK	REVIEWED DISCIPLINE MANAGER	APPROVED ALLIANCE MANAGER
SNP	DJW	MRH	TI
DESIGNED: RGK	DESIGN REVIEW: DJW		

GEOLOGICAL LONGITUDINAL SECTION
SHEET 1 OF 11

SCALE	CONTRACT No	DRAWING No	AMDT
AS SHOWN	PA3748	GT-151	0

\\nz-akl-fas02\Puhoi\Further North - PAA\300 Design\300.5 Technical\01-Drawing Production\CADD\Drawings\GT-151_GT-161.dwg Plot Date: 16 September, 2013 - 3:59 PM

KEY

- COLLUVIUM
- ALLUVIUM
- SOIL } PAKIRI FORMATION
- ROCK } PAKIRI FORMATION
- MANGAKAHIA COMPLEX (Kk) (NORTHLAND ALLOCHTHON)

BOREHOLE
(5m W) OFFSET / DIRECTION FROM ROAD
RS-CW
HW
<----- N≥50 SPT N VALUES ≥50 BELOW THIS DEPTH WHERE SPT CARRIED OUT
MW
SW

MEASURED PIEZOMETRIC READING ---------------->

PIEZOMETER - SCREEN INTERVAL ---------------->

INFERRED GEOLOGICAL BOUNDARY

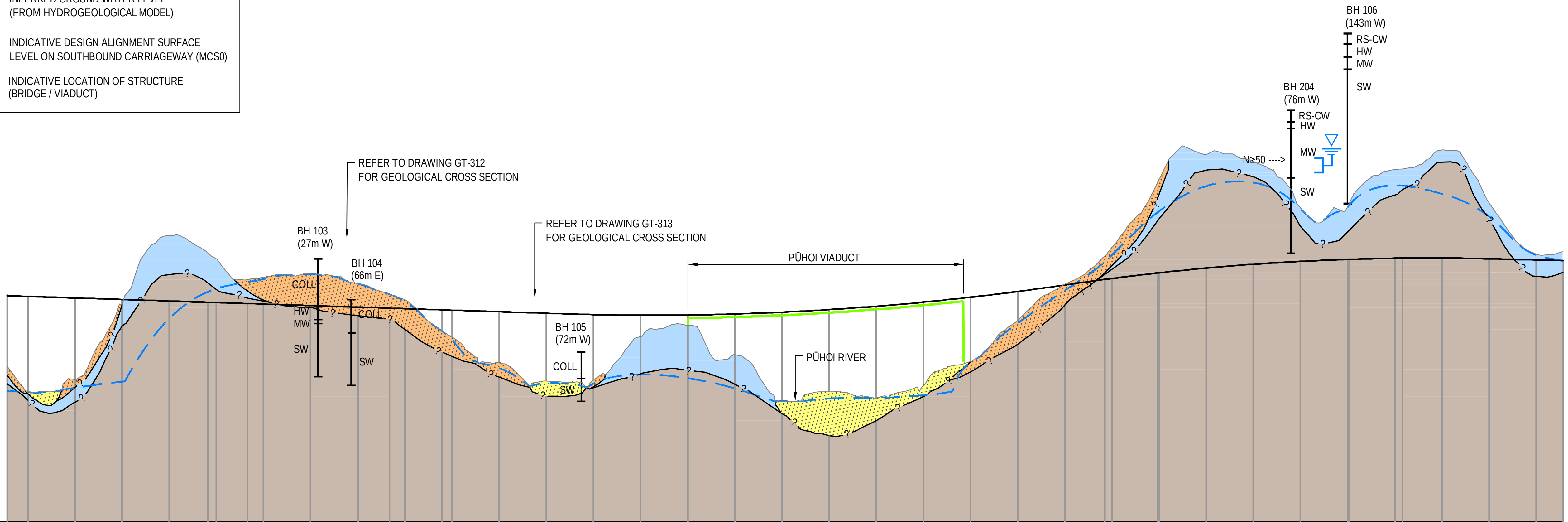
INFERRED GROUND WATER LEVEL (FROM HYDROGEOLOGICAL MODEL)

INDICATIVE DESIGN ALIGNMENT SURFACE LEVEL ON SOUTHBOUND CARRIAGEWAY (MCS0)

INDICATIVE LOCATION OF STRUCTURE (BRIDGE / VIADUCT)

NOTES

1. LOCAL VARIATIONS OR ANOMALIES IN GROUND CONDITIONS CAN OCCUR IN THE NATURAL ENVIRONMENT, PARTICULARLY BETWEEN DISCRETE TEST HOLE LOCATIONS
2. REFER TO DRAWINGS GT-201 TO GT-215 FOR BOREHOLE LOCATIONS
3. VERTICAL EXAGGERATION IS 5:1. GEOLOGICAL BOUNDARIES ARE TO BE REGARDED AS INDICATIVE ONLY
4. BOREHOLE ABBREVIATIONS: RS = RESIDUAL SOIL
   CW = COMPLETELY WEATHERED
   HW = HIGHLY WEATHERED
   MW = MODERATELY WEATHERED
   SW = SLIGHTLY WEATHERED
   UN = UNWEATHERED
   COLL = COLLUVIUM
5. POTENTIAL BLASTING REQUIREMENTS:
   NOT APPLICABLE = BLASTING IS NOT APPLICABLE FOR THE INDICATIVE DESIGN ALIGNMENT
   BLASTING NOT EXPECTED = BLASTING IS NOT EXPECTED TO BE REQUIRED FOR EXCAVATION OF THE INDICATIVE DESIGN ALIGNMENT
   BLASTING MAY BE REQUIRED = BLASTING MAY BE REQUIRED FOR ECONOMICAL EXCAVATION OF THE INDICATIVE DESIGN ALIGNMENT
   BLASTING CAN BE EXPECTED = BLASTING CAN BE EXPECTED TO BE REQUIRED FOR ECONOMICAL EXCAVATION OF THE INDICATIVE DESIGN ALIGNMENT



DESIGN SURFACE LEVEL	22.781	22.457	22.133	21.808	21.484	21.160	20.836	20.512	20.188	19.864	19.539	19.215	18.933	18.810	18.853	19.064
EXISTING SURFACE LEVEL	2.625	5.145	20.996	35.679	30.745	26.874	27.559	25.486	22.105	14.145	8.739	4.814	5.126	14.249	16.667	10.409
CHAINAGE	63600.000	63550.000	63500.000	63450.000	63408.894 63400.000	63366.894 63350.000	63300.000	63250.000	63216.355 63200.000	63160.355 63150.000	63100.000	63050.000	63000.000	62950.000	62900.000	62850.000

DESIGN SURFACE LEVEL	19.440	19.984	20.694	21.571	22.615	23.825	25.202	26.589	27.784	28.786	29.597	30.215	30.641	30.874	30.915	30.764	30.526
EXISTING SURFACE LEVEL	0.501	2.583	1.235	3.870	8.957	17.654	25.393	33.171	47.662	52.955	51.389	41.581	41.887	49.743	53.828	42.621	31.711
CHAINAGE	62800.000	62750.000	62700.000	62650.000	62600.000	62550.000	62500.000	62457.550 62450.000	62401.550 62400.000	62350.000	62300.000	62250.000	62200.000 62197.963	62150.000 62141.963	62100.000	62050.000	62000.000

POTENTIAL BLASTING REQUIREMENTS (REFER TO NOTE 5): NOT APPLICABLE (CH 63600 – 63500) | BLASTING MAY BE REQUIRED (CH 63500 – 63350) | BLASTING NOT EXPECTED (CH 63350 – 63200) | NOT APPLICABLE (CH 63200 – 62500) | BLASTING NOT EXPECTED (CH 62500 – 62450) | BLASTING MAY BE REQUIRED (CH 62450 – 62050) | BLASTING NOT EXPECTED (CH 62050 – 62000)

LONGITUDINAL SECTION - MCS0 (CH 62000 TO CH 63600)

HORIZONTAL SCALE 1:5000 @ A3
VERTICAL SCALE 1:1000 @ A3

HORIZONTAL 1:5,000
VERTICAL 1:1,000
@ A3 SIZE
0 25 50 75 100 125m
0 5 10 15 20 25m

AMD	DATE	DESIGN REVIEW	REVD D. MGR	APP'D A. MGR	PURPOSE OF ISSUE / AMENDMENT
0	30/08/13	DJW	MRH	TI	ISSUED FOR NOR / CONSENT

FURTHER NORTH

DISCLAIMER
The information shown on this drawing is solely for the purposes of supporting RMA applications for statutory approvals. All information shown is subject to review for compliance with approved consents and the outcomes of final design.

ARA TŪHONO - PŪHOI TO WELLSFORD
PŪHOI TO WARKWORTH - FOR RMA APPROVALS

DRAWN	DRAFTING CHECK	REVIEWED DISCIPLINE MANAGER	APPROVED ALLIANCE MANAGER
SNP	DJW	MRH	TI
DESIGNED RGK	DESIGN REVIEW DJW		

GEOLOGICAL LONGITUDINAL SECTION
SHEET 2 OF 11

SCALE	CONTRACT No	DRAWING No	AMDT
AS SHOWN	PA3748	GT-152	0

KEY

COLLUVIUM
ALLUVIUM
SOIL } PAKIRI FORMATION
ROCK }
MANGAKAHIA COMPLEX (Kk) (NORTHLAND ALLOCHTHON)

MEASURED PIEZOMETRIC READING ---------------->
PIEZOMETER - SCREEN INTERVAL ----------------->

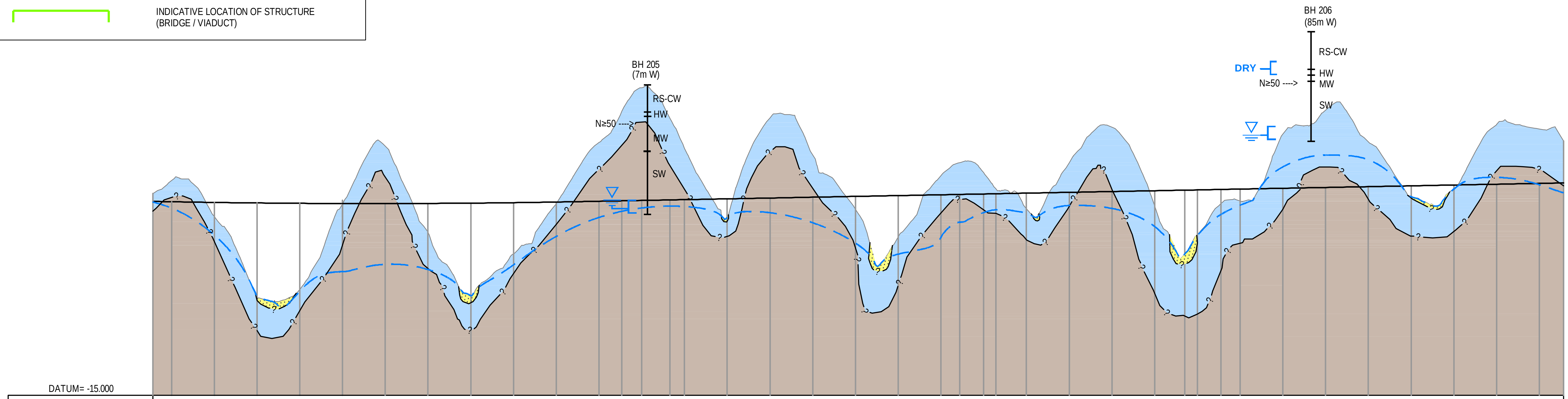
BOREHOLE
(5m W) OFFSET / DIRECTION FROM ROAD
RS-CW
HW
MW
SW
<----- N≥50 SPT N VALUES ≥50 BELOW THIS DEPTH WHERE SPT CARRIED OUT

INFERRED GEOLOGICAL BOUNDARY
INFERRED GROUND WATER LEVEL (FROM HYDROGEOLOGICAL MODEL)
INDICATIVE DESIGN ALIGNMENT SURFACE LEVEL ON SOUTHBOUND CARRIAGEWAY (MCS0)
INDICATIVE LOCATION OF STRUCTURE (BRIDGE / VIADUCT)

NOTES

1. LOCAL VARIATIONS OR ANOMALIES IN GROUND CONDITIONS CAN OCCUR IN THE NATURAL ENVIRONMENT, PARTICULARLY BETWEEN DISCRETE TEST HOLE LOCATIONS
2. REFER TO DRAWINGS GT-201 TO GT-215 FOR BOREHOLE LOCATIONS
3. VERTICAL EXAGGERATION IS 5:1. GEOLOGICAL BOUNDARIES ARE TO BE REGARDED AS INDICATIVE ONLY
4. BOREHOLE ABBREVIATIONS: RS = RESIDUAL SOIL
   CW = COMPLETELY WEATHERED
   HW = HIGHLY WEATHERED
   MW = MODERATELY WEATHERED
   SW = SLIGHTLY WEATHERED
   UN = UNWEATHERED
   COLL = COLLUVIUM
5. POTENTIAL BLASTING REQUIREMENTS:
   NOT APPLICABLE = BLASTING IS NOT APPLICABLE FOR THE INDICATIVE DESIGN ALIGNMENT
   BLASTING NOT EXPECTED = BLASTING IS NOT EXPECTED TO BE REQUIRED FOR EXCAVATION OF THE INDICATIVE DESIGN ALIGNMENT
   BLASTING MAY BE REQUIRED = BLASTING MAY BE REQUIRED FOR ECONOMICAL EXCAVATION OF THE INDICATIVE DESIGN ALIGNMENT
   BLASTING CAN BE EXPECTED = BLASTING CAN BE EXPECTED TO BE REQUIRED FOR ECONOMICAL EXCAVATION OF THE INDICATIVE DESIGN ALIGNMENT

REFER TO DRAWING GT-231 FOR GEOLOGICAL CROSS SECTION



CHAINAGE	DESIGN SURFACE LEVEL	EXISTING SURFACE LEVEL
61950.000	30.325	35.281
61900.000	30.163	26.833
61850.000	30.039	8.128
61800.000	29.954	9.787
61750.000	29.908	29.833
61700.000	29.900	43.323
61650.000	29.930	23.209
61600.000	29.999	8.333
61550.000	30.106	18.162
61500.000	30.252	29.914
61450.000	30.433	44.168
61423.157		
61400.000	30.623	57.012
61367.157		
61350.000	30.813	42.896
61300.000	31.003	26.883
61250.000	31.193	49.974
61200.000	31.383	41.256
61150.000	31.573	28.585
61100.000	31.763	22.094
61050.000	31.953	36.440
61027.876		
61000.000	32.143	37.143
60985.876		
60950.000	32.333	28.737
60900.000	32.523	39.476
60850.000	32.713	47.757
60800.000	32.903	29.298
60764.575		
60750.000	33.093	22.636
60722.575		
60700.000	33.283	30.510
60650.000	33.473	46.188
60600.000	33.663	51.774
60550.000	33.853	44.378
60500.000	34.043	31.511
60450.000	34.233	33.404
60400.000	34.423	48.381
60350.000	34.613	47.371

POTENTIAL BLASTING REQUIREMENTS (REFER TO NOTE 5):

NOT APPLICABLE / BLASTING NOT EXPECTED | BLASTING MAY BE REQUIRED | NOT APPLICABLE / BLASTING NOT EXPECTED | BLASTING MAY BE REQUIRED | NOT APPLICABLE / BLASTING NOT EXPECTED | BLASTING MAY BE REQUIRED | NOT APPLICABLE / BLASTING NOT EXPECTED | BLASTING MAY BE REQUIRED | NOT APPLICABLE / BLASTING NOT EXPECTED | BLASTING MAY BE REQUIRED | NOT APPLICABLE / BLASTING NOT EXPECTED | BLASTING MAY BE REQUIRED

LONGITUDINAL SECTION - MCS0 (CH 60350 TO CH 61950)

HORIZONTAL SCALE 1:5000 @ A3
VERTICAL SCALE 1:1000 @ A3

HORIZONTAL 1:5,000 VERTICAL 1:1,000 @ A3 SIZE
0 25 50 75 100 125m
0 5 10 15 20 25m

AMD	DATE	DESIGN REVIEW	REV'D D. MGR	APP'D A. MGR	PURPOSE OF ISSUE / AMENDMENT
0	30/08/13	DJW	MRH	TI	ISSUED FOR NOR / CONSENT

FURTHER NORTH

ARA TŪHONO - PŪHOI TO WELLSFORD
PŪHOI TO WARKWORTH - FOR RMA APPROVALS

DRAWN SNP | DRAFTING CHECK DJW | REVIEWED DISCIPLINE MANAGER MRH | APPROVED ALLIANCE MANAGER TI
DESIGNED RGK | DESIGN REVIEW DJW

GEOLOGICAL LONGITUDINAL SECTION
SHEET 3 OF 11

SCALE AS SHOWN | CONTRACT No PA3748 | DRAWING No GT-153 | AMDT 0

\\nz-akl-fas02\Puhoi\Further North - PAA\300 Design\300.5 Technical\01-Drawing Production\CADD\Drawings\GT-151_GT-161.dwg   Plot Date: 16 September, 2013 - 4:00 PM

KEY

- COLLUVIUM
- ALLUVIUM
- SOIL } PAKIRI FORMATION
- ROCK }
- MANGAKAHIA COMPLEX (Kk) (NORTHLAND ALLOCHTHON)

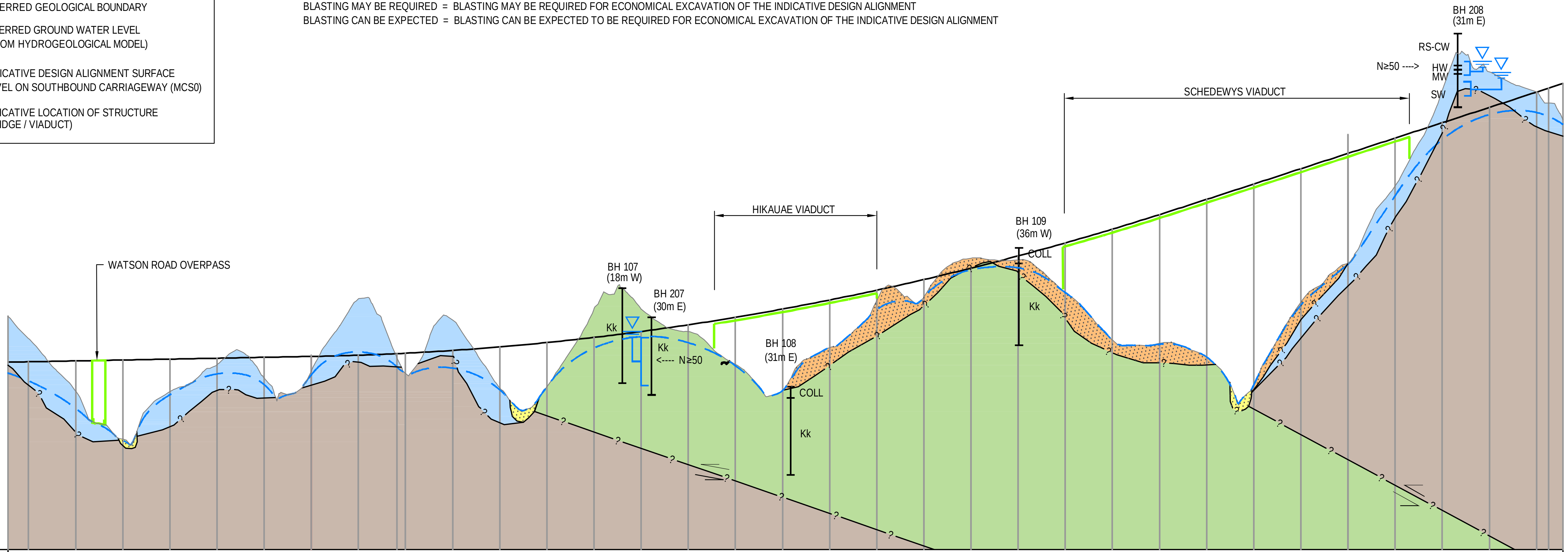
BOREHOLE
(5m W) OFFSET / DIRECTION FROM ROAD
RS-CW
HW
MW
SW

MEASURED PIEZOMETRIC READING ---------------->
PIEZOMETER - SCREEN INTERVAL ----------------->
<----- N≥50 SPT N VALUES ≥50 BELOW THIS DEPTH WHERE SPT CARRIED OUT

- INFERRED GEOLOGICAL BOUNDARY
- INFERRED GROUND WATER LEVEL (FROM HYDROGEOLOGICAL MODEL)
- INDICATIVE DESIGN ALIGNMENT SURFACE LEVEL ON SOUTHBOUND CARRIAGEWAY (MCS0)
- INDICATIVE LOCATION OF STRUCTURE (BRIDGE / VIADUCT)

NOTES

1. LOCAL VARIATIONS OR ANOMALIES IN GROUND CONDITIONS CAN OCCUR IN THE NATURAL ENVIRONMENT, PARTICULARLY BETWEEN DISCRETE TEST HOLE LOCATIONS
2. REFER TO DRAWINGS GT-201 TO GT-215 FOR BOREHOLE LOCATIONS
3. VERTICAL EXAGGERATION IS 5:1. GEOLOGICAL BOUNDARIES ARE TO BE REGARDED AS INDICATIVE ONLY
4. BOREHOLE ABBREVIATIONS: RS = RESIDUAL SOIL
   CW = COMPLETELY WEATHERED
   HW = HIGHLY WEATHERED
   MW = MODERATELY WEATHERED
   SW = SLIGHTLY WEATHERED
   UN = UNWEATHERED
   COLL = COLLUVIUM
5. POTENTIAL BLASTING REQUIREMENTS:
   NOT APPLICABLE = BLASTING IS NOT APPLICABLE FOR THE INDICATIVE DESIGN ALIGNMENT
   BLASTING NOT EXPECTED = BLASTING IS NOT EXPECTED TO BE REQUIRED FOR EXCAVATION OF THE INDICATIVE DESIGN ALIGNMENT
   BLASTING MAY BE REQUIRED = BLASTING MAY BE REQUIRED FOR ECONOMICAL EXCAVATION OF THE INDICATIVE DESIGN ALIGNMENT
   BLASTING CAN BE EXPECTED = BLASTING CAN BE EXPECTED TO BE REQUIRED FOR ECONOMICAL EXCAVATION OF THE INDICATIVE DESIGN ALIGNMENT



DESIGN SURFACE LEVEL	34.803	34.993	35.183	35.373	35.563	35.753	35.943	36.199	36.620	37.208	37.962	38.883	39.971	41.225	42.647	44.234
EXISTING SURFACE LEVEL	39.784	28.586	18.386	28.463	34.173	31.369	32.809	48.174	32.369	43.668	29.220	29.484	46.035	45.959	41.201	34.281
CHAINAGE	60300.000	60250.000	60200.000	60150.000	60100.000	60050.000	60000.000	59950.000	59908.892 59900.000	59850.000	59800.000	59750.000	59700.000	59650.000	59600.000	59550.000

DESIGN SURFACE LEVEL	45.989	47.910	49.998	52.252	54.673	57.261	60.015	62.936	66.024	69.256	72.506	75.756	79.006	82.256	85.506	88.756	92.006
EXISTING SURFACE LEVEL	28.631	37.808	47.829	48.541	56.772	56.446	49.508	39.428	38.709	35.823	29.887	47.489	55.644 55.644	72.101	92.311	96.328	92.056
CHAINAGE	59500.000	59450.000	59400.000	59350.000	59300.000	59250.000	59200.000	59150.000	59100.000	59050.000	59000.000	58950.000	58900.000 58900.000	58850.000	58800.000	58750.000	58700.000 58687.293

POTENTIAL BLASTING REQUIREMENTS (REFER TO NOTE 5)
<---- BLASTING NOT APPLICABLE OR NOT EXPECTED TO BE REQUIRED FOR MOST CUTS IN THIS SECTION ---->
BLASTING MAY BE REQUIRED
NOT APPLICABLE

LONGITUDINAL SECTION - MCS0 (CH 58700 TO CH 60300)

HORIZONTAL SCALE 1:5000 @ A3
VERTICAL SCALE 1:1000 @ A3

HORIZONTAL 1:5,000 — 0 25 50 75 100 125m
VERTICAL 1:1,000 — 0 5 10 15 20 25m
@ A3 SIZE

AMD	DATE	DESIGN REVIEW	REV'D D. MGR	APP'D A. MGR	PURPOSE OF ISSUE / AMENDMENT
0	30/08/13	DJW	MRH	TI	ISSUED FOR NOR / CONSENT

FURTHER NORTH

DISCLAIMER
The information shown on this drawing is solely for the purposes of supporting RMA applications for statutory approvals. All information shown is subject to review for compliance with approved consents and the outcomes of final design.

ARA TŪHONO - PŪHOI TO WELLSFORD
PŪHOI TO WARKWORTH - FOR RMA APPROVALS

DRAWN	DRAFTING CHECK	REVIEWED DISCIPLINE MANAGER	APPROVED ALLIANCE MANAGER
SNP	DJW	MRH	TI
DESIGNED RGK	DESIGN REVIEW DJW		

GEOLOGICAL LONGITUDINAL SECTION
SHEET 4 OF 11

SCALE	CONTRACT No	DRAWING No	AMDT
AS SHOWN	PA3748	GT-154	0

KEY

- COLLUVIUM
- ALLUVIUM
- SOIL } PAKIRI FORMATION
- ROCK } PAKIRI FORMATION
- MANGAKAHIA COMPLEX (Kk) (NORTHLAND ALLOCHTHON)

BOREHOLE

MEASURED PIEZOMETRIC READING ---------------->

(5m W) OFFSET / DIRECTION FROM ROAD

RS-CW

HW

<----- N≥50 SPT N VALUES ≥50 BELOW THIS DEPTH WHERE SPT CARRIED OUT

MW

SW

PIEZOMETER - SCREEN INTERVAL ----------------->

INFERRED GEOLOGICAL BOUNDARY

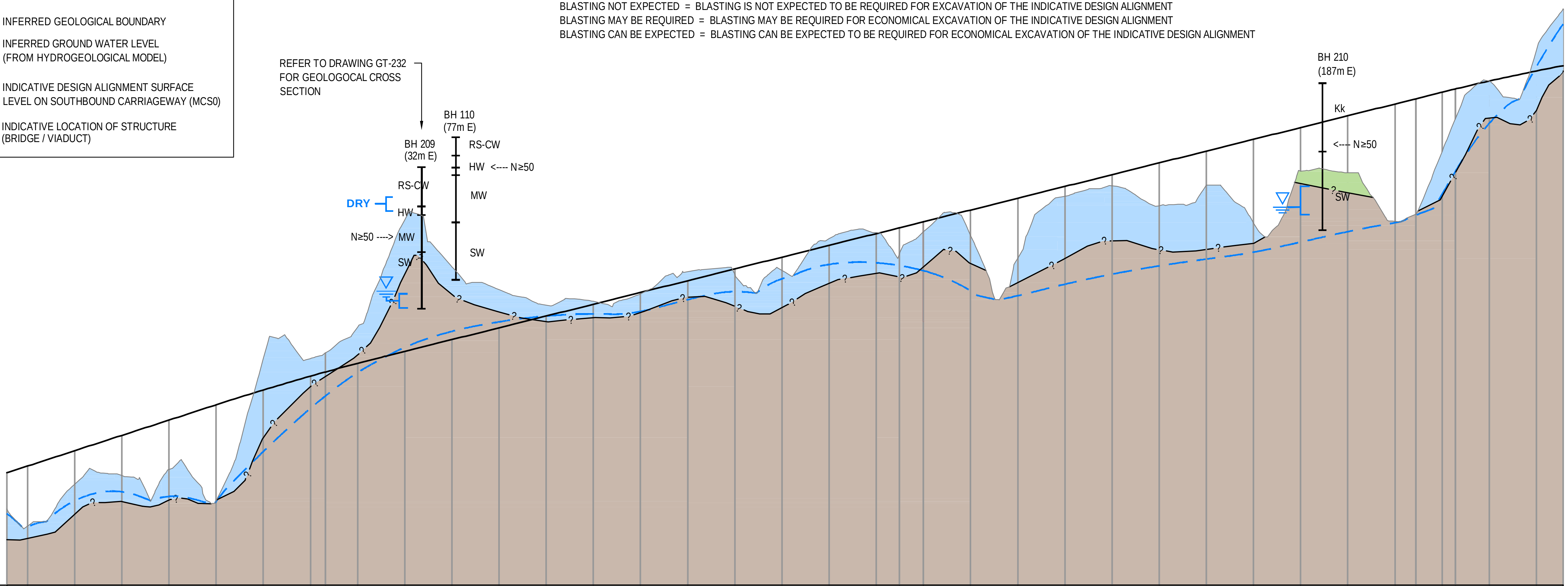
INFERRED GROUND WATER LEVEL (FROM HYDROGEOLOGICAL MODEL)

INDICATIVE DESIGN ALIGNMENT SURFACE LEVEL ON SOUTHBOUND CARRIAGEWAY (MCS0)

INDICATIVE LOCATION OF STRUCTURE (BRIDGE / VIADUCT)

NOTES

1. LOCAL VARIATIONS OR ANOMALIES IN GROUND CONDITIONS CAN OCCUR IN THE NATURAL ENVIRONMENT, PARTICULARLY BETWEEN DISCRETE TEST HOLE LOCATIONS
2. REFER TO DRAWINGS GT-201 TO GT-215 FOR BOREHOLE LOCATIONS
3. VERTICAL EXAGGERATION IS 5:1. GEOLOGICAL BOUNDARIES ARE TO BE REGARDED AS INDICATIVE ONLY
4. BOREHOLE ABBREVIATIONS: RS = RESIDUAL SOIL
   CW = COMPLETELY WEATHERED
   HW = HIGHLY WEATHERED
   MW = MODERATELY WEATHERED
   SW = SLIGHTLY WEATHERED
   UN = UNWEATHERED
   COLL = COLLUVIUM
5. POTENTIAL BLASTING REQUIREMENTS:
   NOT APPLICABLE = BLASTING IS NOT APPLICABLE FOR THE INDICATIVE DESIGN ALIGNMENT
   BLASTING NOT EXPECTED = BLASTING IS NOT EXPECTED TO BE REQUIRED FOR EXCAVATION OF THE INDICATIVE DESIGN ALIGNMENT
   BLASTING MAY BE REQUIRED = BLASTING MAY BE REQUIRED FOR ECONOMICAL EXCAVATION OF THE INDICATIVE DESIGN ALIGNMENT
   BLASTING CAN BE EXPECTED = BLASTING CAN BE EXPECTED TO BE REQUIRED FOR ECONOMICAL EXCAVATION OF THE INDICATIVE DESIGN ALIGNMENT



DATUM= 70.000

CHAINAGE	DESIGN SURFACE LEVEL	EXISTING SURFACE LEVEL
58650.000	95.256	82.538
58600.000	98.506	91.407
58550.000	101.756	93.253
58500.000	105.006	94.538
58450.000	108.255	87.818
58400.000	111.397	117.997
58350.000	114.330	118.099
58334.175		
58300.000	117.054	124.755
58250.000	119.589	147.517
58200.000	122.089	137.559
58150.000	124.589	132.687
58100.000	127.089	129.419
58050.000	129.589	130.213
58000.000	132.089	131.811
57950.000	134.589	136.491
57900.000	137.089	135.928
57850.000	139.589	136.758
57800.000	142.089	143.500
57750.000	144.589	144.779
57725.517		
57700.000	147.089	144.934
57650.000	149.589	144.196
57600.000	152.089	139.352
57550.000	154.589	152.514
57500.000	157.089	154.720
57450.000	159.589	150.516
57400.000	162.089	154.854
57350.000	164.589	146.880
57300.000	167.089	157.867
57250.000	169.589	157.528
57200.000	172.089	147.193
57177.948		
57150.000	174.589	162.016
57135.948		
57100.000	176.965	177.009
57050.000	179.111	183.491

POTENTIAL BLASTING REQUIREMENTS (REFER TO NOTE 5)

58650 – 58400	58400 – 58300	58300 – 58100	58100 – 57750	57750 – 57050
<------ NOT APPLICABLE ------>	BLASTING NOT EXPECTED	BLASTING MAY BE REQUIRED	BLASTING NOT EXPECTED	<------ NOT APPLICABLE ------>

LONGITUDINAL SECTION - MCS0 (CH 57050 TO CH 58650)

HORIZONTAL SCALE 1:5000 @ A3

VERTICAL SCALE 1:1000 @ A3

HORIZONTAL 1:5,000 0 25 50 75 100 125m

VERTICAL 1:1,000 0 5 10 15 20 25m

@ A3 SIZE

AMD	DATE	DESIGN REVIEW	REV'D D. MGR	APP'D A. MGR	PURPOSE OF ISSUE / AMENDMENT
0	30/08/13	DJW	MRH	TI	ISSUED FOR NOR / CONSENT

FURTHER NORTH

DISCLAIMER

The information shown on this drawing is solely for the purposes of supporting RMA applications for statutory approvals. All information shown is subject to review for compliance with approved consents and the outcomes of final design.

ARA TŪHONO - PŪHOI TO WELLSFORD

PŪHOI TO WARKWORTH - FOR RMA APPROVALS

DRAWN	DRAFTING CHECK	REVIEWED DISCIPLINE MANAGER	APPROVED ALLIANCE MANAGER
SNP	DJW	MRH	TI
DESIGNED RGK	DESIGN REVIEW DJW		

GEOLOGICAL LONGITUDINAL SECTION

SHEET 5 OF 11

SCALE	CONTRACT No	DRAWING No	AMDT
AS SHOWN	PA3748	GT-155	0

\\nz-akl-fas02\Puhoi\Further North - PAA\300 Design\300.5 Technical\01-Drawing Production\CADD\Drawings\GT-151_GT-161.dwg Plot Date: 16 September, 2013 - 4:01 PM

NOTES

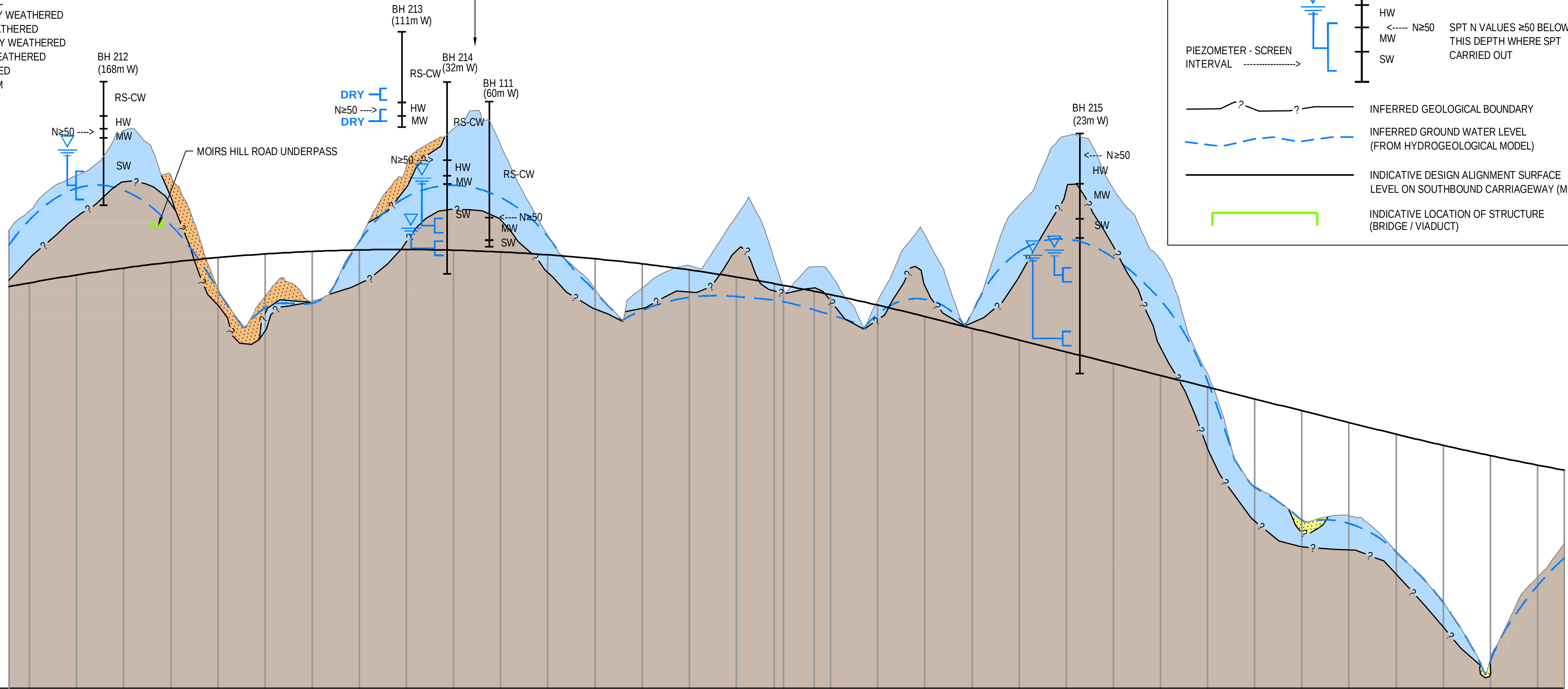
1. LOCAL VARIATIONS OR ANOMALIES IN GROUND CONDITIONS CAN OCCUR IN THE NATURAL ENVIRONMENT, PARTICULARLY BETWEEN DISCRETE TEST HOLE LOCATIONS
2. REFER TO DRAWINGS GT-201 TO GT-215 FOR BOREHOLE LOCATIONS
3. VERTICAL EXAGGERATION IS 5:1. GEOLOGICAL BOUNDARIES ARE TO BE REGARDED AS INDICATIVE ONLY
4. BOREHOLE ABBREVIATIONS: RS = RESIDUAL SOIL
   CW = COMPLETELY WEATHERED
   HW = HIGHLY WEATHERED
   MW = MODERATELY WEATHERED
   SW = SLIGHTLY WEATHERED
   UN = UNWEATHERED
   COLL = COLLUVIUM

NOTES (CONTINUED)

5. POTENTIAL BLASTING REQUIREMENTS:
   NOT APPLICABLE = BLASTING IS NOT APPLICABLE FOR THE INDICATIVE DESIGN ALIGNMENT
   BLASTING NOT EXPECTED = BLASTING IS NOT EXPECTED TO BE REQUIRED FOR EXCAVATION OF THE INDICATIVE DESIGN ALIGNMENT
   BLASTING MAY BE REQUIRED = BLASTING MAY BE REQUIRED FOR ECONOMICAL EXCAVATION OF THE INDICATIVE DESIGN ALIGNMENT
   BLASTING CAN BE EXPECTED = BLASTING CAN BE EXPECTED TO BE REQUIRED FOR ECONOMICAL EXCAVATION OF THE INDICATIVE DESIGN ALIGNMENT

KEY

COLLUVIUM
ALLUVIUM
SOIL, ROCK } PAKIRI FORMATION
MANGAKAHIA COMPLEX (Kk) (NORTHLAND ALLOCHTHON)
MEASURED PIEZOMETRIC READING
PIEZOMETER - SCREEN INTERVAL
BOREHOLE (5m W) OFFSET / DIRECTION FROM ROAD
RS-CW
HW
MW
SW
N≥50 SPT N VALUES ≥50 BELOW THIS DEPTH WHERE SPT CARRIED OUT
INFERRED GEOLOGICAL BOUNDARY
INFERRED GROUND WATER LEVEL (FROM HYDROGEOLOGICAL MODEL)
INDICATIVE DESIGN ALIGNMENT SURFACE LEVEL ON SOUTHBOUND CARRIAGEWAY (MCS0)
INDICATIVE LOCATION OF STRUCTURE (BRIDGE / VIADUCT)



CHAINAGE	DESIGN SURFACE LEVEL	EXISTING SURFACE LEVEL
57000.000	181.029	196.285
56950.000	182.717	203.819
56900.000	184.175	213.439
56850.000	185.404	203.728
56800.000	186.404	179.788
56750.000	187.175	178.142
56700.000	187.716	177.099
56650.000	188.028	189.840
56600.000	188.110	205.820
56550.000	187.963	213.733
56500.000	187.587	210.310
56450.000	186.981	191.125
56400.000	186.146	179.700
56350.000	185.082	179.902
56300.000	183.788	184.703
56250.000	182.265	195.208
56209.617		
56200.000	180.512	179.812
56167.617		
56150.000	178.531	182.854
56100.000	176.320	177.208
56050.000	173.886	191.233
56000.000	171.386	174.748
55950.000	168.886	197.494
55900.000	166.386	212.220
55850.000	163.886	200.947
55800.000	161.386	186.038
55750.000	158.886	161.752
55700.000	156.386	137.868
55650.000	153.886	130.549
55600.000	151.386	131.669
55550.000	148.898	123.994
55500.000	146.545	113.203
55450.000	144.359	101.293
55400.000	142.339	118.526

POTENTIAL BLASTING REQUIREMENTS (REFER TO NOTE 5)									
BLASTING CAN BE EXPECTED	NOT APPLICABLE	BLASTING MAY BE REQUIRED	NOT APPLICABLE	BLASTING NOT EXPECTED	BLASTING MAY BE REQUIRED	BLASTING NOT EXPECTED	BLASTING MAY BE REQUIRED	BLASTING CAN BE EXPECTED	NOT APPLICABLE

LONGITUDINAL SECTION - MCS0 (CH 55400 TO CH 57000)

HORIZONTAL SCALE 1:5000 @ A3
VERTICAL SCALE 1:1000 @ A3

HORIZONTAL 1:5,000 — 0 25 50 75 100 125m
VERTICAL 1:1,000 — 0 5 10 15 20 25m
@ A3 SIZE

AMD	DATE	DESIGN REVIEW	REV'D D. MGR	APP'D A. MGR	PURPOSE OF ISSUE / AMENDMENT
0	30/08/13	DJW	MRH	TI	ISSUED FOR NOR / CONSENT

FURTHER NORTH

DISCLAIMER
The information shown on this drawing is solely for the purposes of supporting RMA applications for statutory approvals. All information shown is subject to review for compliance with approved consents and the outcomes of final design.

ARA TŪHONO - PŪHOI TO WELLSFORD
PŪHOI TO WARKWORTH - FOR RMA APPROVALS

DRAWN: SNP | DRAFTING CHECK: DJW | REVIEWED DISCIPLINE MANAGER: MRH | APPROVED ALLIANCE MANAGER: TI
DESIGNED: RGK | DESIGN REVIEW: DJW

GEOLOGICAL LONGITUDINAL SECTION
SHEET 6 OF 11

SCALE: AS SHOWN | CONTRACT No: PA3748 | DRAWING No: GT-156 | AMDT: 0

NOTES

1. LOCAL VARIATIONS OR ANOMALIES IN GROUND CONDITIONS CAN OCCUR IN THE NATURAL ENVIRONMENT, PARTICULARLY BETWEEN DISCRETE TEST HOLE LOCATIONS
2. REFER TO DRAWINGS GT-201 TO GT-215 FOR BOREHOLE LOCATIONS
3. VERTICAL EXAGGERATION IS 5:1. GEOLOGICAL BOUNDARIES ARE TO BE REGARDED AS INDICATIVE ONLY
4. BOREHOLE ABBREVIATIONS: RS = RESIDUAL SOIL
   CW = COMPLETELY WEATHERED
   HW = HIGHLY WEATHERED
   MW = MODERATELY WEATHERED
   SW = SLIGHTLY WEATHERED
   UN = UNWEATHERED
   COLL = COLLUVIUM
5. POTENTIAL BLASTING REQUIREMENTS:
   NOT APPLICABLE = BLASTING IS NOT APPLICABLE FOR THE INDICATIVE DESIGN ALIGNMENT
   BLASTING NOT EXPECTED = BLASTING IS NOT EXPECTED TO BE REQUIRED FOR EXCAVATION OF THE INDICATIVE DESIGN ALIGNMENT
   BLASTING MAY BE REQUIRED = BLASTING MAY BE REQUIRED FOR ECONOMICAL EXCAVATION OF THE INDICATIVE DESIGN ALIGNMENT
   BLASTING CAN BE EXPECTED = BLASTING CAN BE EXPECTED TO BE REQUIRED FOR ECONOMICAL EXCAVATION OF THE INDICATIVE DESIGN ALIGNMENT

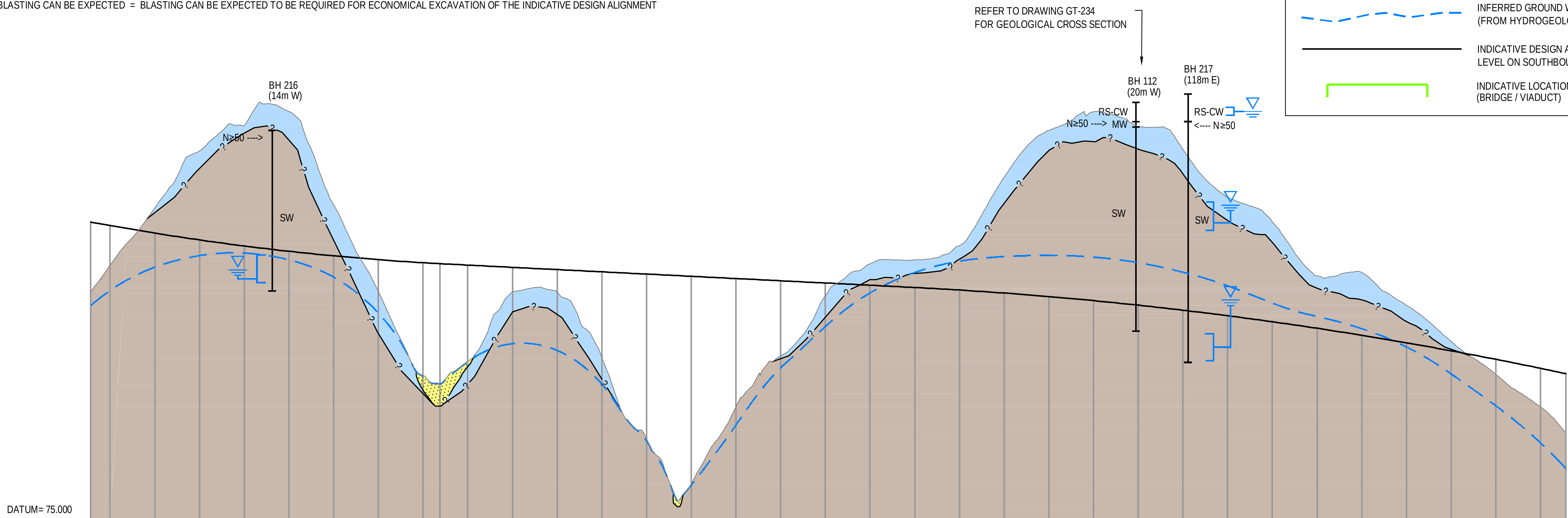
KEY

COLLUVIUM
ALLUVIUM
SOIL } PAKIRI FORMATION
ROCK }
MANGAKAHIA COMPLEX (Kk) (NORTHLAND ALLOCHTHON)

MEASURED PIEZOMETRIC READING ---------------->
PIEZOMETER - SCREEN INTERVAL ---------------->

BOREHOLE
(5m W) OFFSET / DIRECTION FROM ROAD
RS-CW
HW
<----- N≥50 SPT N VALUES ≥50 BELOW THIS DEPTH WHERE SPT CARRIED OUT
MW
SW

INFERRED GEOLOGICAL BOUNDARY
INFERRED GROUND WATER LEVEL (FROM HYDROGEOLOGICAL MODEL)
INDICATIVE DESIGN ALIGNMENT SURFACE LEVEL ON SOUTHBOUND CARRIAGEWAY (MCS0)
INDICATIVE LOCATION OF STRUCTURE (BRIDGE / VIADUCT)



DESIGN SURFACE LEVEL	140.486	138.800	137.280	135.927	134.741	133.721	132.868	132.182		131.650	131.150	130.650	130.150	129.650	129.150	128.650	128.150	127.650	127.150	126.649	126.080	125.400	124.609	123.707	122.693	121.569	120.333	118.986	117.528	115.959	114.279	112.488	110.586	108.572
EXISTING SURFACE LEVEL	131.604	144.462	157.147	162.822	165.999	145.144	125.788	106.971		110.048	125.658	125.572	110.915	92.789	82.691	99.953	111.379	124.759	131.930	132.813	136.023	151.329	161.800	165.925	162.722	157.546	146.886	141.341	129.240	129.993	122.666	114.573	107.246	99.942
CHAINAGE	55350.000	55300.000	55250.000	55200.000	55150.000	55100.000	55050.000	55000.000	54981.004	54950.000	54900.000	54850.000	54800.000	54750.000	54700.000	54650.000	54600.000	54550.000	54500.000	54450.000	54400.000	54350.000	54300.000	54250.000	54200.000	54150.000	54100.000	54050.000	54000.000	53950.000	53900.000	53850.000	53800.000	53750.000

POTENTIAL BLASTING REQUIREMENTS (REFER TO NOTE 5)	NOT APPLICABLE	BLASTING CAN BE EXPECTED	NOT APPLICABLE	BLASTING CAN BE EXPECTED	NOT APPLICABLE

LONGITUDINAL SECTION - MCS0 (CH 53750 TO CH 55350)

HORIZONTAL SCALE 1:5000 @ A3
VERTICAL SCALE 1:1000 @ A3

HORIZONTAL 1:5,000 — 0 25 50 75 100 125m
VERTICAL 1:1,000 — 0 5 10 15 20 25m
@ A3 SIZE

AMD	DATE	DESIGN REVIEW	REV'D D. MGR	APP'D A. MGR	PURPOSE OF ISSUE / AMENDMENT
0	30/08/13	DJW	MRH	TI	ISSUED FOR NOR / CONSENT

FURTHER NORTH

DISCLAIMER
The information shown on this drawing is solely for the purposes of supporting RMA applications for statutory approvals.
All information shown is subject to review for compliance with approved consents and the outcomes of final design.

ARA TŪHONO - PŪHOI TO WELLSFORD
PŪHOI TO WARKWORTH - FOR RMA APPROVALS

DRAWN SNP | DRAFTING CHECK DJW | REVIEWED DISCIPLINE MANAGER MRH | APPROVED ALLIANCE MANAGER TI
DESIGNED RGK | DESIGN REVIEW DJW

GEOLOGICAL LONGITUDINAL SECTION
SHEET 7 OF 11

SCALE AS SHOWN | CONTRACT No PA3748 | DRAWING No GT-157 | AMDT 0

\\nz-akl-fas02\Puhoi\Further North - PAA\300 Design\300.5 Technical\01-Drawing Production\CADD\Drawings\GT-151_GT-161.dwg Plot Date: 16 September, 2013 - 4:04 PM

NOTES

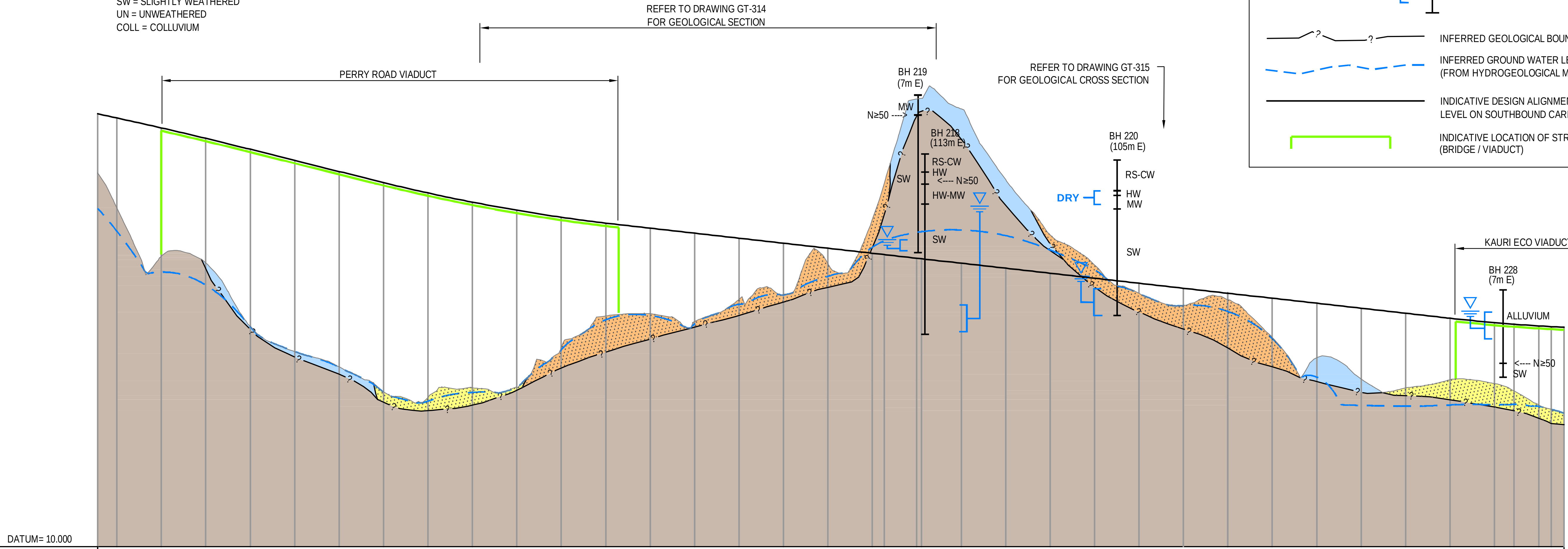
1. LOCAL VARIATIONS OR ANOMALIES IN GROUND CONDITIONS CAN OCCUR IN THE NATURAL ENVIRONMENT, PARTICULARLY BETWEEN DISCRETE TEST HOLE LOCATIONS
2. REFER TO DRAWINGS GT-201 TO GT-215 FOR BOREHOLE LOCATIONS
3. VERTICAL EXAGGERATION IS 5:1. GEOLOGICAL BOUNDARIES ARE TO BE REGARDED AS INDICATIVE ONLY
4. BOREHOLE ABBREVIATIONS: RS = RESIDUAL SOIL
   CW = COMPLETELY WEATHERED
   HW = HIGHLY WEATHERED
   MW = MODERATELY WEATHERED
   SW = SLIGHTLY WEATHERED
   UN = UNWEATHERED
   COLL = COLLUVIUM

NOTES (CONTINUED)

5. POTENTIAL BLASTING REQUIREMENTS:
   NOT APPLICABLE = BLASTING IS NOT APPLICABLE FOR THE INDICATIVE DESIGN ALIGNMENT
   BLASTING NOT EXPECTED = BLASTING IS NOT EXPECTED TO BE REQUIRED FOR EXCAVATION OF THE INDICATIVE DESIGN ALIGNMENT
   BLASTING MAY BE REQUIRED = BLASTING MAY BE REQUIRED FOR ECONOMICAL EXCAVATION OF THE INDICATIVE DESIGN ALIGNMENT
   BLASTING CAN BE EXPECTED = BLASTING CAN BE EXPECTED TO BE REQUIRED FOR ECONOMICAL EXCAVATION OF THE INDICATIVE DESIGN ALIGNMENT

KEY

COLLUVIUM
ALLUVIUM
SOIL } PAKIRI FORMATION
ROCK }
MANGAKAHIA COMPLEX (Kk) (NORTHLAND ALLOCHTHON)
MEASURED PIEZOMETRIC READING ---------------->
PIEZOMETER - SCREEN INTERVAL ---------------->
BOREHOLE
(5m W) OFFSET / DIRECTION FROM ROAD
RS-CW
HW
<----- N≥50 SPT N VALUES ≥50 BELOW THIS DEPTH WHERE SPT CARRIED OUT
MW
SW
INFERRED GEOLOGICAL BOUNDARY
INFERRED GROUND WATER LEVEL (FROM HYDROGEOLOGICAL MODEL)
INDICATIVE DESIGN ALIGNMENT SURFACE LEVEL ON SOUTHBOUND CARRIAGEWAY (MCS0)
INDICATIVE LOCATION OF STRUCTURE (BRIDGE / VIADUCT)



CHAINAGE	DESIGN SURFACE LEVEL	EXISTING SURFACE LEVEL
53700.000	106.448	86.212
53650.000	104.212	75.373
53600.000	101.865	73.886
53550.000	99.408	59.544
53500.000	96.908	53.908
53450.000	94.408	50.480
53400.000	91.914	44.795
53350.000	89.589	43.588
53300.000	87.515	45.768
53250.000	85.691	45.846
53200.000	84.117	54.832
53150.000	82.793	61.915
53100.000	81.657	62.414
53050.000	80.532	60.660
53000.000	79.407	65.662
52950.000	78.282	66.776
52900.000	77.157	73.709
52850.000 52836.754	76.032	83.605
52800.000 52794.754	74.907	110.711
52750.000	73.782	108.497
52700.000	72.657	92.592
52650.000	71.532	80.154
52600.000	70.407	73.380
52550.000	69.282	66.986
52500.000	68.157	64.299
52450.000	67.032	65.615
52400.000	65.907	57.109
52350.000	64.782	52.508
52300.000	63.657	47.712
52250.000	62.532	45.732
52200.000	61.407	47.572
52150.000	60.421	46.717
52127.909		
52100.000 52085.909	59.685	41.908

POTENTIAL BLASTING REQUIREMENTS (REFER TO NOTE 5): NOT APPLICABLE | BLASTING CAN BE EXPECTED | BLASTING NOT EXPECTED | NOT APPLICABLE

LONGITUDINAL SECTION - MCS0 (CH 52100 TO CH 53700)

HORIZONTAL SCALE 1:5000 @ A3
VERTICAL SCALE 1:1000 @ A3

HORIZONTAL 1:5,000 VERTICAL 1:1,000 @ A3 SIZE
0 25 50 75 100 125m
0 5 10 15 20 25m

AMD	DATE	DESIGN REVIEW	REV'D D. MGR	APP'D A. MGR	PURPOSE OF ISSUE / AMENDMENT
0	30/08/13	DJW	MRH	TI	ISSUED FOR NOR / CONSENT

FURTHER NORTH

DISCLAIMER
The information shown on this drawing is solely for the purposes of supporting RMA applications for statutory approvals. All information shown is subject to review for compliance with approved consents and the outcomes of final design.

ARA TŪHONO - PŪHOI TO WELLSFORD
PŪHOI TO WARKWORTH - FOR RMA APPROVALS
DRAWN SNP | DRAFTING CHECK DJW | REVIEWED DISCIPLINE MANAGER MRH | APPROVED ALLIANCE MANAGER TI
DESIGNED RGK | DESIGN REVIEW DJW

GEOLOGICAL LONGITUDINAL SECTION
SHEET 8 OF 11
SCALE AS SHOWN | CONTRACT No PA3748 | DRAWING No GT-158 | AMDT 0

\\nz-akl-fas02\Puhoi\Further North - PAA\300 Design\300.5 Technical\01-Drawing Production\CADD\Drawings\GT-151_GT-161.dwg Plot Date: 16 September, 2013 - 4:04 PM

NOTES

1. LOCAL VARIATIONS OR ANOMALIES IN GROUND CONDITIONS CAN OCCUR IN THE NATURAL ENVIRONMENT, PARTICULARLY BETWEEN DISCRETE TEST HOLE LOCATIONS
2. REFER TO DRAWINGS GT-201 TO GT-215 FOR BOREHOLE LOCATIONS
3. VERTICAL EXAGGERATION IS 5:1. GEOLOGICAL BOUNDARIES ARE TO BE REGARDED AS INDICATIVE ONLY
4. BOREHOLE ABBREVIATIONS: RS = RESIDUAL SOIL
   CW = COMPLETELY WEATHERED
   HW = HIGHLY WEATHERED
   MW = MODERATELY WEATHERED
   SW = SLIGHTLY WEATHERED
   UN = UNWEATHERED
   COLL = COLLUVIUM
5. POTENTIAL BLASTING REQUIREMENTS:
   NOT APPLICABLE = BLASTING IS NOT APPLICABLE FOR THE INDICATIVE DESIGN ALIGNMENT
   BLASTING NOT EXPECTED = BLASTING IS NOT EXPECTED TO BE REQUIRED FOR EXCAVATION OF THE INDICATIVE DESIGN ALIGNMENT
   BLASTING MAY BE REQUIRED = BLASTING MAY BE REQUIRED FOR ECONOMICAL EXCAVATION OF THE INDICATIVE DESIGN ALIGNMENT
   BLASTING CAN BE EXPECTED = BLASTING CAN BE EXPECTED TO BE REQUIRED FOR ECONOMICAL EXCAVATION OF THE INDICATIVE DESIGN ALIGNMENT

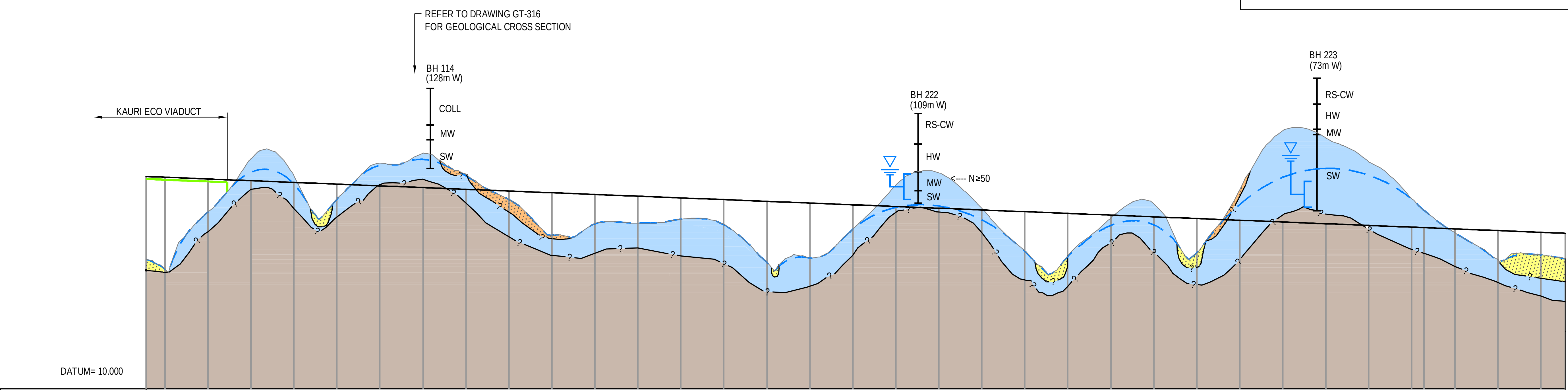
KEY

COLLUVIUM
ALLUVIUM
SOIL } PAKIRI FORMATION
ROCK }
MANGAKAHIA COMPLEX (Kk) (NORTHLAND ALLOCHTHON)

BOREHOLE
(5m W) OFFSET / DIRECTION FROM ROAD
RS-CW
HW
MW <----- N≥50 SPT N VALUES ≥50 BELOW THIS DEPTH WHERE SPT CARRIED OUT
SW

MEASURED PIEZOMETRIC READING ------------------>
PIEZOMETER - SCREEN INTERVAL ------------------>

INFERRED GEOLOGICAL BOUNDARY
INFERRED GROUND WATER LEVEL (FROM HYDROGEOLOGICAL MODEL)
INDICATIVE DESIGN ALIGNMENT SURFACE LEVEL ON SOUTHBOUND CARRIAGEWAY (MCS0)
INDICATIVE LOCATION OF STRUCTURE (BRIDGE / VIADUCT)



CHAINAGE	DESIGN SURFACE LEVEL	EXISTING SURFACE LEVEL
52050.000	59.196	37.863
52000.000	58.796	51.120
51950.000 / 51949.764	58.396	63.476
51900.000	57.996	59.578
51850.000	57.596	54.103
51800.000	57.196	62.516
51750.000	56.796	64.803
51700.000	56.396	59.945
51650.000	55.996	54.033
51600.000	55.596	45.663
51550.000	55.196	48.417
51500.000	54.796	48.503
51450.000	54.396	49.430
51400.000	53.996	48.255
51350.000	53.596	39.372
51300.000	53.196	40.437
51250.000	52.796	47.171
51200.000	52.396	57.396
51150.000	51.996	60.229
51100.000	51.596	51.970
51050.000	51.196	42.055
51000.000	50.796	40.932
50950.000	50.396	49.686
50900.000	49.996	52.994
50850.000	49.596	41.607
50800.000	49.196	56.311
50750.000	48.796	70.018
50700.000	48.396	68.351
50650.000	47.996	62.783
50600.000 / 50585.652	47.596	54.225
50550.000	47.196	46.292
50500.000	46.796	40.069
50450.000	46.396	41.188

POTENTIAL BLASTING REQUIREMENTS (REFER TO NOTE 5)				
NOT APPLICABLE	<— BLASTING NOT APPLICABLE OR NOT EXPECTED FOR CUTS IN THIS SECTION —>	BLASTING MAY BE REQUIRED	BLASTING NOT EXPECTED	NOT APPLICABLE

LONGITUDINAL SECTION - MCS0 (CH 50450 TO CH 52050)

HORIZONTAL SCALE 1:5000 @ A3
VERTICAL SCALE 1:1000 @ A3

HORIZONTAL 1:5,000 0 25 50 75 100 125m
VERTICAL 1:1,000 0 5 10 15 20 25m
@ A3 SIZE

AMD	DATE	DESIGN REVIEW	REV'D D. MGR	APP'D A. MGR	PURPOSE OF ISSUE / AMENDMENT
0	30/08/13	DJW	MRH	TI	ISSUED FOR NOR / CONSENT

FURTHER NORTH

ARA TŪHONO - PŪHOI TO WELLSFORD
PŪHOI TO WARKWORTH - FOR RMA APPROVALS

DRAWN SNP | DRAFTING CHECK DJW | REVIEWED DISCIPLINE MANAGER MRH | APPROVED ALLIANCE MANAGER TI
DESIGNED RGK | DESIGN REVIEW DJW

GEOLOGICAL LONGITUDINAL SECTION
SHEET 9 OF 11

SCALE AS SHOWN | CONTRACT No PA3748 | DRAWING No GT-159 | AMDT 0

\\nz-akl-fas02\Puhoi\Further North - PAA\300 Design\300.5 Technical\01-Drawing Production\CADD\Drawings\GT-151_GT-161.dwg Plot Date: 16 September, 2013 - 4:04 PM

KEY

COLLUVIUM
ALLUVIUM
SOIL } PAKIRI FORMATION
ROCK }
MANGAKAHIA COMPLEX (Kk) (NORTHLAND ALLOCHTHON)

BOREHOLE
(5m W) OFFSET / DIRECTION FROM ROAD
RS-CW
HW
<----- N≥50 SPT N VALUES ≥50 BELOW THIS DEPTH WHERE SPT CARRIED OUT
MW
SW

MEASURED PIEZOMETRIC READING ---------------->

PIEZOMETER - SCREEN INTERVAL ----------------->

INFERRED GEOLOGICAL BOUNDARY

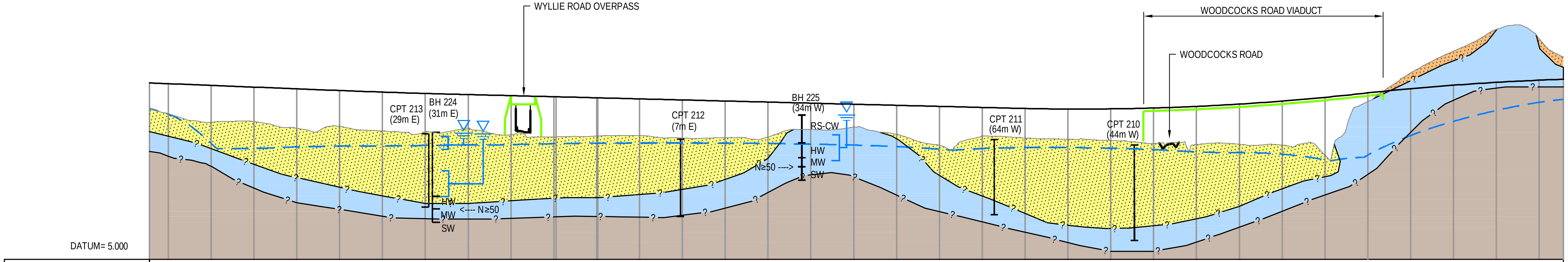
INFERRED GROUND WATER LEVEL (FROM HYDROGEOLOGICAL MODEL)

INDICATIVE DESIGN ALIGNMENT SURFACE LEVEL ON SOUTHBOUND CARRIAGEWAY (MCS0)

INDICATIVE LOCATION OF STRUCTURE (BRIDGE / VIADUCT)

NOTES

1. LOCAL VARIATIONS OR ANOMALIES IN GROUND CONDITIONS CAN OCCUR IN THE NATURAL ENVIRONMENT, PARTICULARLY BETWEEN DISCRETE TEST HOLE LOCATIONS
2. REFER TO DRAWINGS GT-201 TO GT-215 FOR BOREHOLE LOCATIONS
3. VERTICAL EXAGGERATION IS 5:1. GEOLOGICAL BOUNDARIES ARE TO BE REGARDED AS INDICATIVE ONLY
4. BOREHOLE ABBREVIATIONS: RS = RESIDUAL SOIL
   CW = COMPLETELY WEATHERED
   HW = HIGHLY WEATHERED
   MW = MODERATELY WEATHERED
   SW = SLIGHTLY WEATHERED
   UN = UNWEATHERED
   COLL = COLLUVIUM
5. POTENTIAL BLASTING REQUIREMENTS:
   NOT APPLICABLE = BLASTING IS NOT APPLICABLE FOR THE INDICATIVE DESIGN ALIGNMENT
   BLASTING NOT EXPECTED = BLASTING IS NOT EXPECTED TO BE REQUIRED FOR EXCAVATION OF THE INDICATIVE DESIGN ALIGNMENT
   BLASTING MAY BE REQUIRED = BLASTING MAY BE REQUIRED FOR ECONOMICAL EXCAVATION OF THE INDICATIVE DESIGN ALIGNMENT
   BLASTING CAN BE EXPECTED = BLASTING CAN BE EXPECTED TO BE REQUIRED FOR ECONOMICAL EXCAVATION OF THE INDICATIVE DESIGN ALIGNMENT



DESIGN SURFACE LEVEL	45.996	45.596	45.196	44.796	44.397	44.032	43.718	43.452	43.202	42.952	42.702	42.452	42.202	41.952	41.702	41.452
EXISTING SURFACE LEVEL	38.969	37.019	37.194	35.627	36.100	34.956	34.781	35.705	34.076	33.588	33.781	33.881	33.321	33.413	33.560	35.341
CHAINAGE	50400.000	50350.000	50300.000	50250.000	50200.000	50150.000	50100.000	50050.000	50000.000	49950.000 49947.573	49900.000 49898.573	49850.000	49800.000	49750.000	49700.000	49650.000

DESIGN SURFACE LEVEL	41.202	40.952	40.702	40.452	40.207	40.079	40.118	40.324	40.696	41.235	41.941	42.814	43.845	44.820	45.639	46.301	46.808
EXISTING SURFACE LEVEL	35.970	34.148	31.639	33.751	33.342	33.040	32.722	32.066	31.808	31.840	31.680	29.294	41.848	48.500	53.580	58.649	56.483
CHAINAGE	49600.000	49550.000	49500.000	49450.000	49400.000	49350.000	49300.000	49250.000	49200.000	49150.000	49100.000	49050.000	49000.000	48950.000	48900.000	48850.000	48800.000

POTENTIAL BLASTING REQUIREMENTS (REFER TO NOTE 5)	NOT APPLICABLE (CH 50400 to CH 49000)	BLASTING NOT EXPECTED

LONGITUDINAL SECTION - MCS0 (CH48800 TO CH 50400)

HORIZONTAL SCALE 1:5000 @ A3
VERTICAL SCALE 1:1000 @ A3

HORIZONTAL 1:5,000 — 0 25 50 75 100 125m
VERTICAL 1:1,000 — 0 5 10 15 20 25m
@ A3 SIZE

AMD	DATE	DESIGN REVIEW	REV'D D. MGR	APP'D A. MGR	PURPOSE OF ISSUE / AMENDMENT
0	30/08/13	DJW	MRH	TI	ISSUED FOR NOR / CONSENT

FURTHER NORTH

DISCLAIMER
The information shown on this drawing is solely for the purposes of supporting RMA applications for statutory approvals.
All information shown is subject to review for compliance with approved consents and the outcomes of final design.

ARA TŪHONO - PŪHOI TO WELLSFORD
PŪHOI TO WARKWORTH - FOR RMA APPROVALS

DRAWN	DRAFTING CHECK	REVIEWED DISCIPLINE MANAGER	APPROVED ALLIANCE MANAGER
SNP	DJW	MRH	TI
DESIGNED: RGK	DESIGN REVIEW: DJW		

GEOLOGICAL LONGITUDINAL SECTION
SHEET 10 OF 11

SCALE	CONTRACT No	DRAWING No	AMDT
AS SHOWN	PA3748	GT-160	0

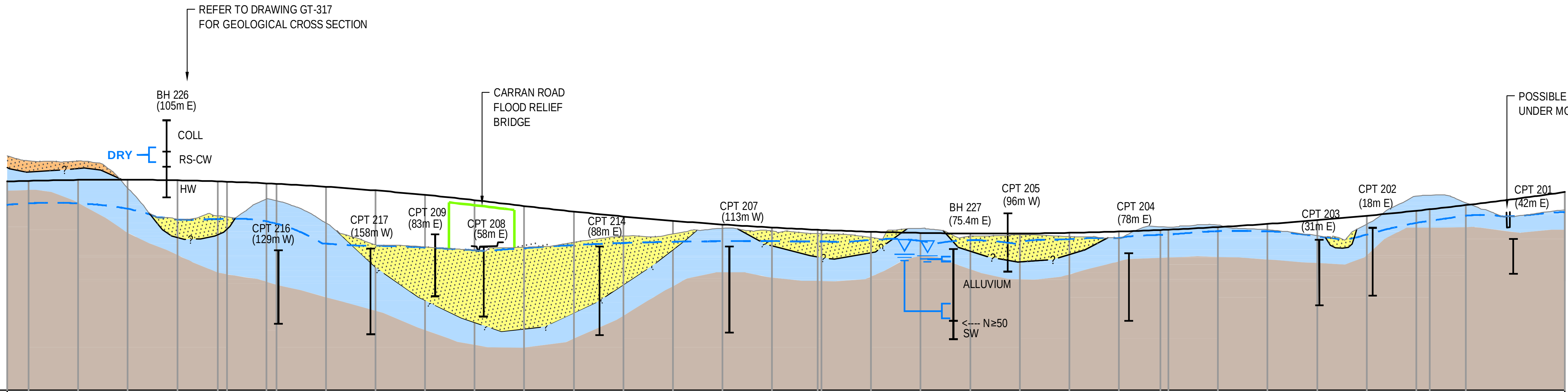
\\nz-akl-fas02\Puhoi\Further North - PAA\300 Design\300.5 Technical\01-Drawing Production\CADD\Drawings\GT-151_GT-161.dwg Plot Date: 16 September, 2013 - 4:05 PM

NOTES

1. LOCAL VARIATIONS OR ANOMALIES IN GROUND CONDITIONS CAN OCCUR IN THE NATURAL ENVIRONMENT, PARTICULARLY BETWEEN DISCRETE TEST HOLE LOCATIONS
2. REFER TO DRAWINGS GT-201 TO GT-215 FOR BOREHOLE LOCATIONS
3. VERTICAL EXAGGERATION IS 5:1. GEOLOGICAL BOUNDARIES ARE TO BE REGARDED AS INDICATIVE ONLY
4. BOREHOLE ABBREVIATIONS: RS = RESIDUAL SOIL
   CW = COMPLETELY WEATHERED
   HW = HIGHLY WEATHERED
   MW = MODERATELY WEATHERED
   SW = SLIGHTLY WEATHERED
   UN = UNWEATHERED
   COLL = COLLUVIUM
5. POTENTIAL BLASTING REQUIREMENTS:
   NOT APPLICABLE = BLASTING IS NOT APPLICABLE FOR THE INDICATIVE DESIGN ALIGNMENT
   BLASTING NOT EXPECTED = BLASTING IS NOT EXPECTED TO BE REQUIRED FOR EXCAVATION OF THE INDICATIVE DESIGN ALIGNMENT
   BLASTING MAY BE REQUIRED = BLASTING MAY BE REQUIRED FOR ECONOMICAL EXCAVATION OF THE INDICATIVE DESIGN ALIGNMENT
   BLASTING CAN BE EXPECTED = BLASTING CAN BE EXPECTED TO BE REQUIRED FOR ECONOMICAL EXCAVATION OF THE INDICATIVE DESIGN ALIGNMENT

KEY

COLLUVIUM
ALLUVIUM
SOIL } PAKIRI FORMATION
ROCK }
MANGAKAHIA COMPLEX (Kk) (NORTHLAND ALLOCHTHON)
BOREHOLE
(5m W) OFFSET / DIRECTION FROM ROAD
RS-CW
HW
MW
SW
<----- N≥50 SPT N VALUES ≥50 BELOW THIS DEPTH WHERE SPT CARRIED OUT
MEASURED PIEZOMETRIC READING ---------------->
PIEZOMETER - SCREEN INTERVAL ---------------->
INFERRED GEOLOGICAL BOUNDARY
INFERRED GROUND WATER LEVEL (FROM HYDROGEOLOGICAL MODEL)
INDICATIVE DESIGN ALIGNMENT SURFACE LEVEL ON SOUTHBOUND CARRIAGEWAY (MCS0)
INDICATIVE LOCATION OF STRUCTURE (BRIDGE / VIADUCT)



CHAINAGE	DESIGN SURFACE LEVEL	EXISTING SURFACE LEVEL
48750.000	47.158	51.207
48700.000	47.351	51.157
48650.000	47.389	45.720
48600.000	47.270	39.400
48558.977 / 48550.000	46.995	39.904
48509.977 / 48500.000	46.564	43.135
48450.000	45.976	38.645
48400.000	45.233	34.248
48350.000	44.333	33.823
48300.000	43.276	33.189
48250.000	42.087	33.781
48200.000	40.971	34.790
48150.000	39.981	36.068
48100.000	39.116	36.471
48050.000	38.376	37.605
48000.000	37.761	37.078
47953.909 / 47950.000	37.270	36.493
47900.000	36.905	35.781
47850.000	36.665	37.608
47800.000	36.550	36.025
47750.000	36.560	36.308
47700.000	36.694	35.939
47650.000	36.954	35.567
47608.202 / 47600.000	37.339	37.861
47550.000	37.849	38.236
47500.000	38.484	37.343
47450.000	39.243	36.159
47400.000	40.128	38.399
47350.000 / 47336.235	41.138	44.122
47300.000	42.273	42.773
47250.000	43.533	40.056
47200.000	44.897	41.289

POTENTIAL BLASTING REQUIREMENTS (REFER TO NOTE 5)	
CH 48750 – CH 48650	BLASTING NOT EXPECTED
CH 48650 – CH 47400	NOT APPLICABLE
CH 47400 – CH 47300	BLASTING NOT EXPECTED
CH 47300 – CH 47200	NOT APPLICABLE

LONGITUDINAL SECTION - MCS0 (CH 47200 TO CH 48750)

HORIZONTAL SCALE 1:5000 @ A3
VERTICAL SCALE 1:1000 @ A3

HORIZONTAL 1:5,000 0 25 50 75 100 125m
VERTICAL 1:1,000 0 5 10 15 20 25m
@ A3 SIZE

AMD	DATE	DESIGN REVIEW	REV'D D. MGR	APP'D A. MGR	PURPOSE OF ISSUE / AMENDMENT
0	30/08/13	DJW	MRH	TI	ISSUED FOR NOR / CONSENT

FURTHER NORTH

DISCLAIMER
The information shown on this drawing is solely for the purposes of supporting RMA applications for statutory approvals. All information shown is subject to review for compliance with approved consents and the outcomes of final design.

ARA TŪHONO - PŪHOI TO WELLSFORD
PŪHOI TO WARKWORTH - FOR RMA APPROVALS

DRAWN SNP | DRAFTING CHECK DJW | REVIEWED DISCIPLINE MANAGER MRH | APPROVED ALLIANCE MANAGER TI
DESIGNED RGK | DESIGN REVIEW DJW

GEOLOGICAL LONGITUDINAL SECTION
SHEET 11 OF 11

SCALE AS SHOWN | CONTRACT No PA3748 | DRAWING No GT-161 | AMDT 0

\\nz-akl-fas02\Puhoi\Further North - PAA\300 Design\300.5 Technical\01-Drawing Production\CADD\Drawings\GT-151_GT-161.dwg Plot Date: 16 September, 2013 - 4:05 PM

Appendix F. Geological Cross Sections – Cuttings

GT-231 Geological Cross Sections - Cuttings - Sheet 1 of 4 - Watson Road Cutting

GT-232 Geological Cross Sections - Cuttings - Sheet 2 of 4 - Wreaks Road Cutting

GT-233 Geological Cross Sections - Cuttings - Sheet 3 of 4 - Moirs Hill North Cutting

GT-234 Geological Cross Sections - Cuttings - Sheet 4 of 4 - Redwoods Road Cutting

KEY

EXISTING FILL
COLLUVIUM
ALLUVIUM

WAITEMATA GROUP (PAKIRI FORMATION)
- RS-CW (RESIDUAL SOIL TO COMPLETELY WEATHERED)
- HW (HIGHLY WEATHERED)
- MW (MODERATELY WEATHERED)
- SW (SLIGHTLY WEATHERED TO UNWEATHERED)

MEASURED PIEZOMETRIC READING ---------------->

PIEZOMETER - SCREEN INTERVAL ---------------->

BOREHOLE
(5m W) OFFSET / DIRECTION FROM SECTION
RS-CW
HW
<----- N≥50 SPT N VALUES ≥50 BELOW THIS DEPTH
MW
SW

INFERRED SHEAR ZONE

INFERRED GEOLOGICAL BOUNDARY

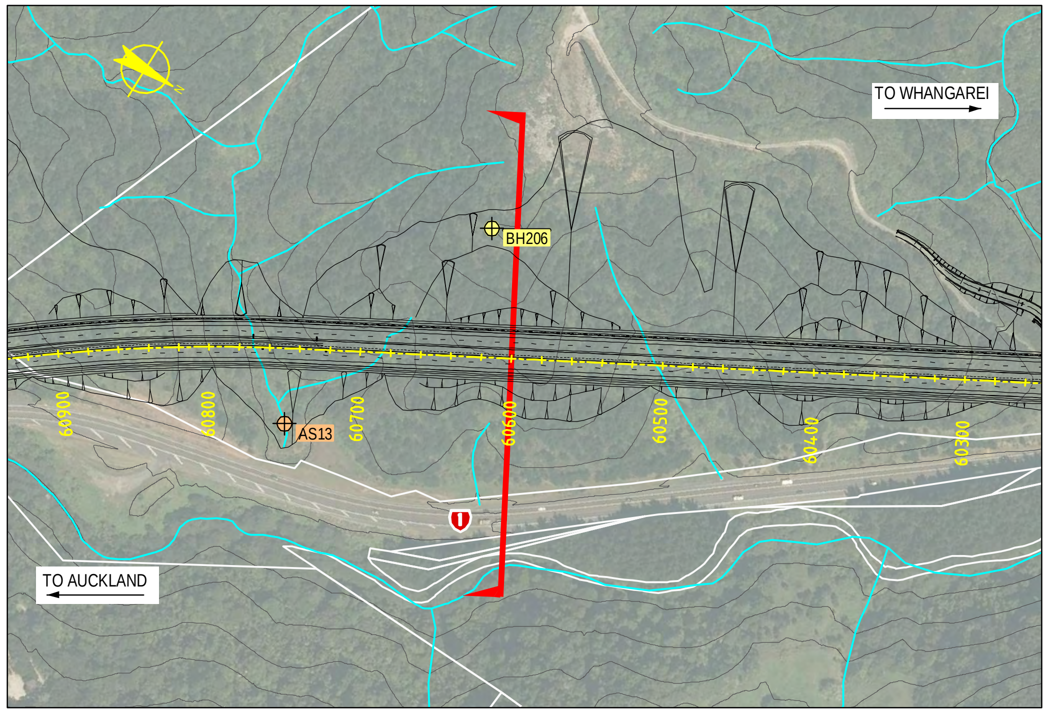
INFERRED GROUND WATER LEVEL (FROM HYDROGEOLOGICAL MODEL)

INFERRED APPARENT BEDDING (SPACING NOT TO SCALE)

INDICATIVE DESIGN SURFACE LEVEL

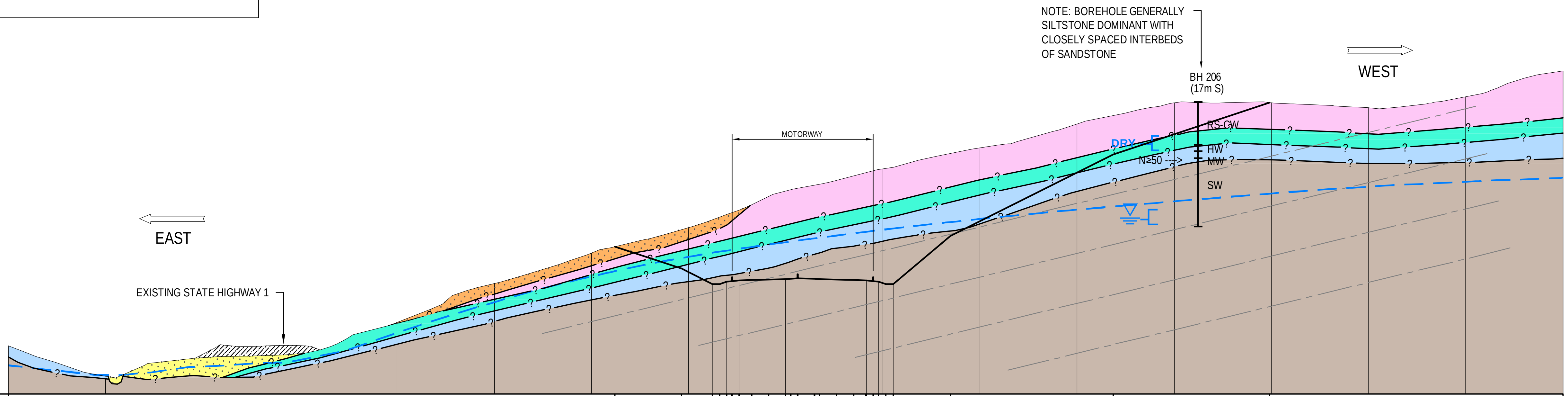
NOTES

1. GENERAL BEDDING DIP AND DIP DIRECTION (MEASURED BY OPTICAL TELEVIEWER): BH206 =16°/ 041
2. APPARENT DIP OF BEDDING SHOWN ON CROSS SECTION (APPARENT DIP IS DEFINED AS THE DIP OF A PLANE AS SEEN IN AN OBLIQUE SECTION)
3. VARIABLE JOINT SETS :- DOMINANT SETS OF NORTHWEST AND SOUTHWEST ORIENTATION
4. REFER TO DRAWING GT-204 FOR SIGNIFICANT GEOTECHNICAL FEATURES



LOCALITY PLAN

0 25 50 75 100 125m
SCALE 1:5,000 @ A3 SIZE



GENERIC DESIGN SURFACE LEVEL	40.355, 35.807, 32.618, 33.118, 33.375, 33.378, 33.453, 33.558, 33.663, 33.833, 33.833, 33.696, 33.663, 33.558, 33.453, 33.378, 33.228, 32.618, 32.618, 42.498, 59.267, 69.999
EXISTING SURFACE LEVEL	19.967, 18.585, 17.757, 16.499, 14.526, 13.997, 13.325, 15.939, 16.376, 17.369, 19.530, 20.077, 19.734, 19.812, 20.026, 19.974, 19.832, 19.113, 20.375, 22.195, 23.459, 24.094, 24.113, 27.450, 28.446, 30.275, 31.340, 31.825, 33.083, 34.219, 35.427, 36.681, 37.456, 38.662, 39.724, 40.109, 41.623, 41.975, 42.844, 44.494, 45.356, 46.538, 46.964, 47.906, 48.788, 51.072, 52.183, 53.287, 53.908, 56.155, 56.709, 58.122, 58.961, 60.381, 61.252, 61.525, 61.941, 64.022, 64.251, 65.661, 66.137, 66.642, 67.801, 68.503, 68.939, 69.204, 69.850, 70.159, 69.875, 69.910, 69.959, 70.143, 69.915, 69.727, 69.715, 69.368, 69.178, 68.942, 68.723, 69.053, 69.711, 70.045, 70.228, 71.804, 72.468, 72.967, 73.976, 74.944, 75.622, 75.795, 76.520
DISTANCE	0.000, 20.000, 40.000, 60.000, 80.000, 100.000, 120.000, 140.000, 160.000, 180.000, 200.000, 220.000, 240.000, 260.000, 280.000, 300.000, 320.000

CROSS SECTION AT CH 60600 (MCS0) - WATSON ROAD

HORIZONTAL SCALE 1:1000 @ A3
VERTICAL SCALE 1:1000 @ A3

0 5 10 15 20 25m
SCALE 1:1,000 @ A3 SIZE

AMD	DATE	DESIGN REVIEW	REV'D D. MGR	APP'D A. MGR	PURPOSE OF ISSUE / AMENDMENT
0	30/08/13	DJW	MRH	TI	ISSUED FOR NOR / CONSENT

FURTHER NORTH

DISCLAIMER
The information shown on this drawing is solely for the purposes of supporting RMA applications for statutory approvals.
All information shown is subject to review for compliance with approved consents and the outcomes of final design.

ARA TŪHONO - PŪHOI TO WELLSFORD
PŪHOI TO WARKWORTH - FOR RMA APPROVALS

DRAWN	DRAFTING CHECK	REVIEWED DISCIPLINE MANAGER	APPROVED ALLIANCE MANAGER
SNP	DJW	MRH	TI
DESIGNED RGK	DESIGN REVIEW DJW		

GEOLOGICAL CROSS SECTIONS
CUTTINGS - SHEET 1 OF 4
WATSON ROAD CUTTING

SCALE	CONTRACT No	DRAWING No	AMDT
AS SHOWN	PA3748	GT-231	0

Plot Date: 29 August , 2013 - 3:28 PM
S:\Further North - PAA\300 Design\300.5 Technical\01-Drawing Production\CADD\Drawings\GT-231_GT-234.dwg

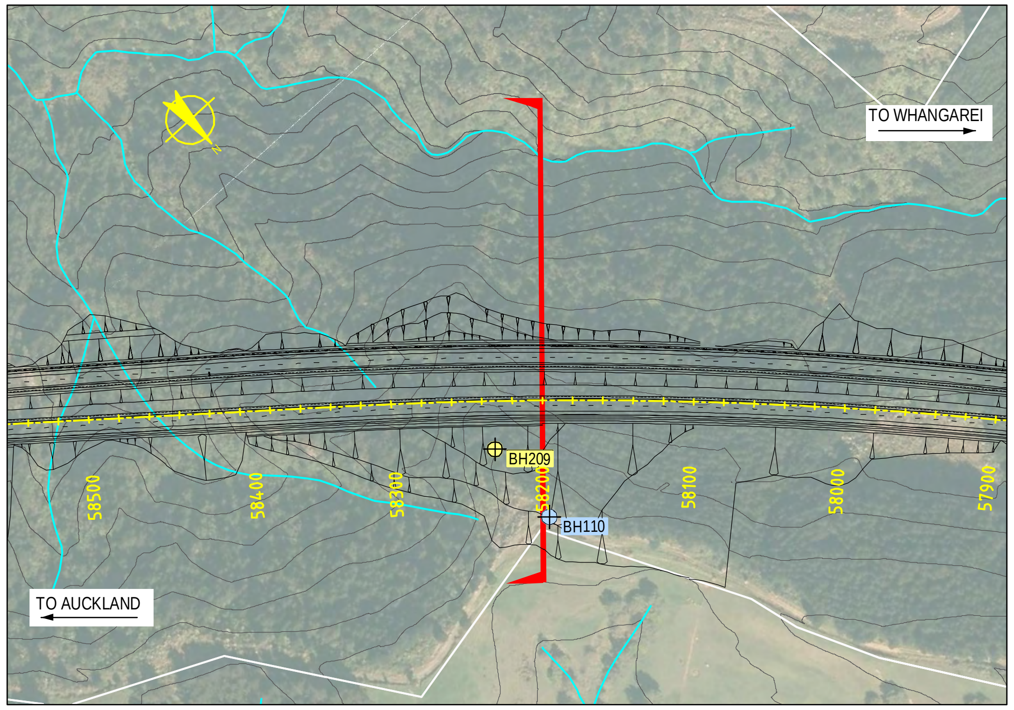
NOTES

1. GENERAL BEDDING DIP AND DIP DIRECTION (MEASURED BY OPTICAL TELEVIEWER): BH110 = 10°/ 198
   BH209 = 18°/ 209

2. APPARENT DIP OF BEDDING SHOWN ON CROSS SECTION. (APPARENT DIP IS DEFINED AS THE DIP OF A PLANE AS SEEN IN AN OBLIQUE SECTION).

3. VARIABLE JOINT SETS - DIP AND DIP DIRECTION:
   BH110 = 30°/ 230
   BH209 = 68°/ 118, 76°/ 082, 72°/ 044

4. REFER TO DRAWING GT-206 FOR SIGNIFICANT GEOTECHNICAL FEATURES.



LOCALITY PLAN

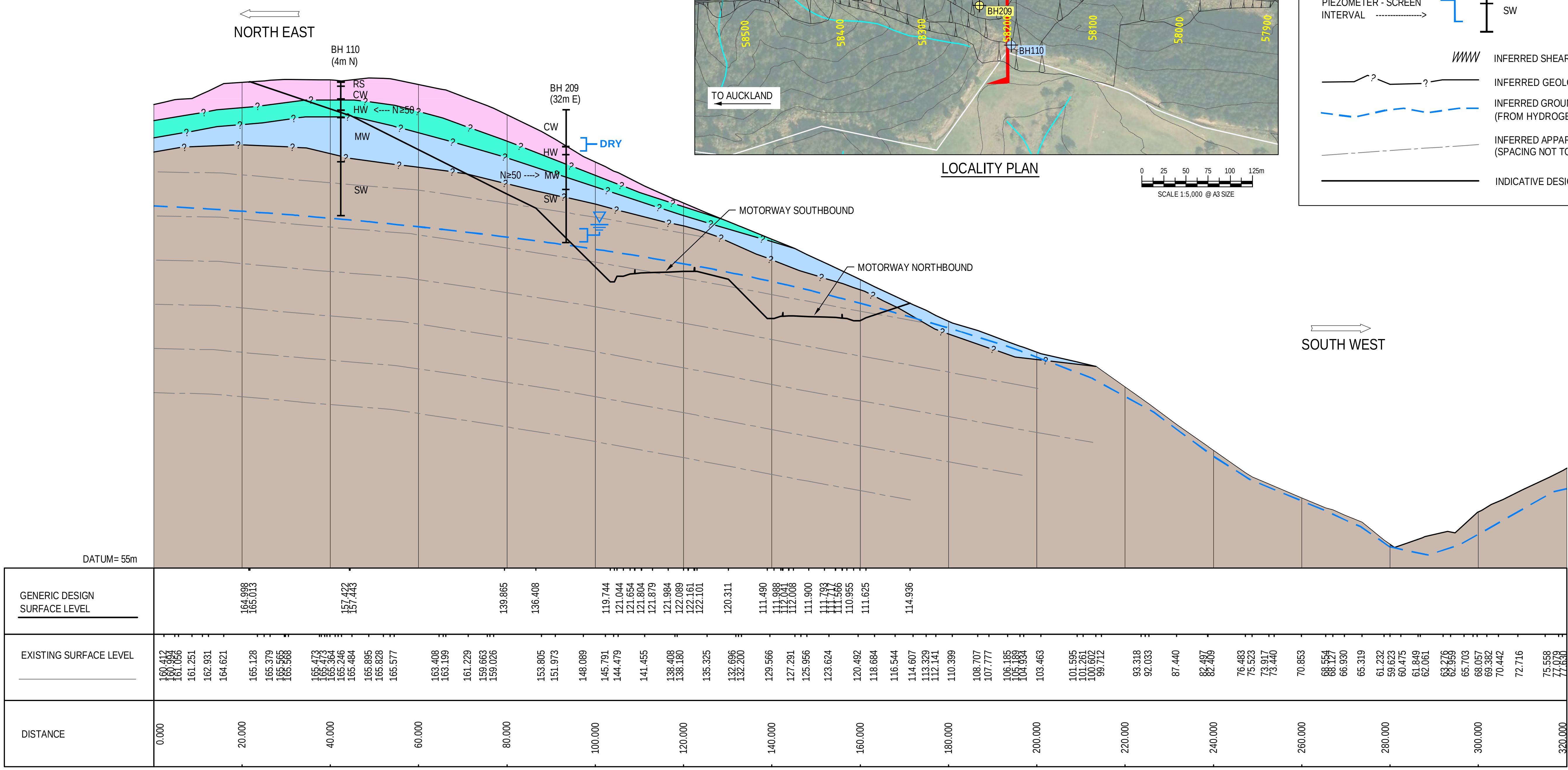
0 25 50 75 100 125m
SCALE 1:5,000 @ A3 SIZE

KEY

COLLUVIUM
ALLUVIUM
WAITEMATA GROUP (PAKIRI FORMATION)
RS-CW (RESIDUAL SOIL TO COMPLETELY WEATHERED)
HW (HIGHLY WEATHERED)
MW (MODERATELY WEATHERED)
SW (SLIGHTLY WEATHERED TO UNWEATHERED)

BOREHOLE
(5m W) OFFSET / DIRECTION FROM SECTION
RS-CW
HW
MW
SW
MEASURED PIEZOMETRIC READING
PIEZOMETER - SCREEN INTERVAL
<---- N≥50 SPT N VALUES ≥50 BELOW THIS DEPTH

INFERRED SHEAR ZONE
INFERRED GEOLOGICAL BOUNDARY
INFERRED GROUND WATER LEVEL (FROM HYDROGEOLOGICAL MODEL)
INFERRED APPARENT BEDDING (SPACING NOT TO SCALE)
INDICATIVE DESIGN SURFACE LEVEL



CROSS SECTION AT CH 58200 (MCS0) - WREAKS ROAD

HORIZONTAL SCALE 1:1000 @ A3
VERTICAL SCALE 1:1000 @ A3

0 5 10 15 20 25m
SCALE 1:1,000 @ A3 SIZE

AMD	DATE	DESIGN REVIEW	REV'D D. MGR	APP'D A. MGR	PURPOSE OF ISSUE / AMENDMENT
0	30/08/13	DJW	MRH	TI	ISSUED FOR NOR / CONSENT

FURTHER NORTH

DISCLAIMER
The information shown on this drawing is solely for the purpose of supporting RMA applications for statutory approvals.
All information shown is subject to review for compliance with approved consents and the outcomes of final design.

ARA TŪHONO - PŪHOI TO WELLSFORD
PŪHOI TO WARKWORTH - FOR RMA APPROVALS

DRAWN	DRAFTING CHECK	REVIEWED DISCIPLINE MANAGER	APPROVED ALLIANCE MANAGER
SNP	DJW	MRH	TI
DESIGNED RGK	DESIGN REVIEW DJW		

GEOLOGICAL CROSS SECTIONS
CUTTINGS - SHEET 2 OF 4
WREAKS ROAD CUTTING

SCALE	CONTRACT No	DRAWING No	AMDT
AS SHOWN	PA3748	GT-232	0

KEY

COLLUVIUM
ALLUVIUM

WAITEMATA GROUP (PAKIRI FORMATION)
- RS-CW (RESIDUAL SOIL TO COMPLETELY WEATHERED)
- HW (HIGHLY WEATHERED)
- MW (MODERATELY WEATHERED)
- SW (SLIGHTLY WEATHERED TO UNWEATHERED)

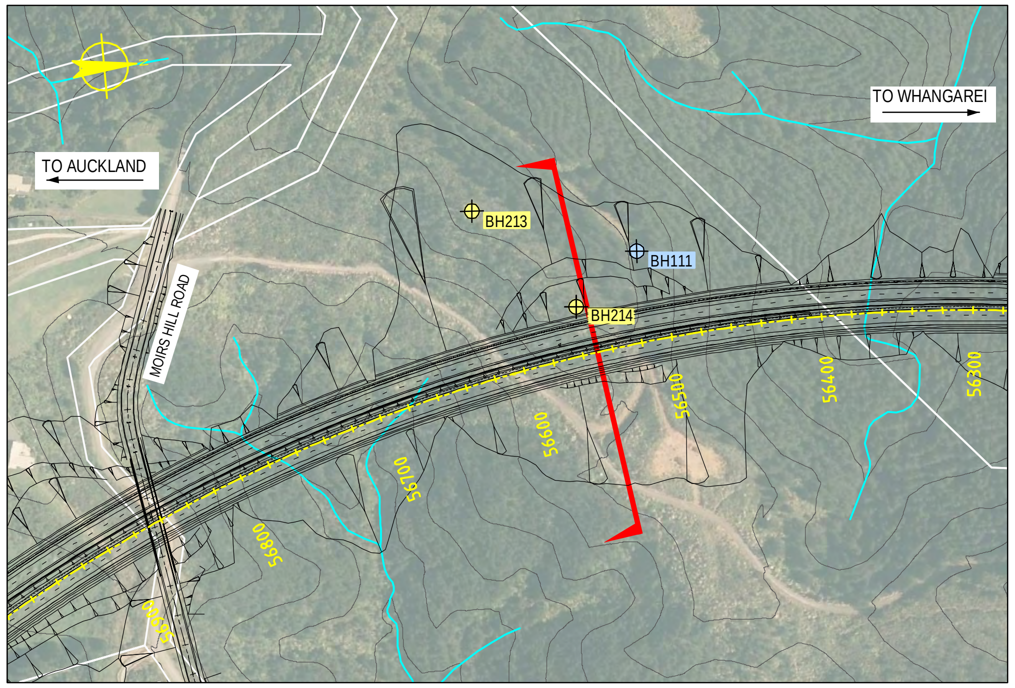
BOREHOLE
(5m W) OFFSET / DIRECTION FROM SECTION
RS-CW
HW
<----- N≥50 SPT N VALUES ≥50 BELOW THIS DEPTH
MW
SW

MEASURED PIEZOMETRIC READING ----------------->
PIEZOMETER - SCREEN INTERVAL ---------------->

INFERRED SHEAR ZONE
INFERRED GEOLOGICAL BOUNDARY
INFERRED GROUND WATER LEVEL (FROM HYDROGEOLOGICAL MODEL)
INFERRED APPARENT BEDDING (SPACING NOT TO SCALE)
INDICATIVE DESIGN SURFACE LEVEL

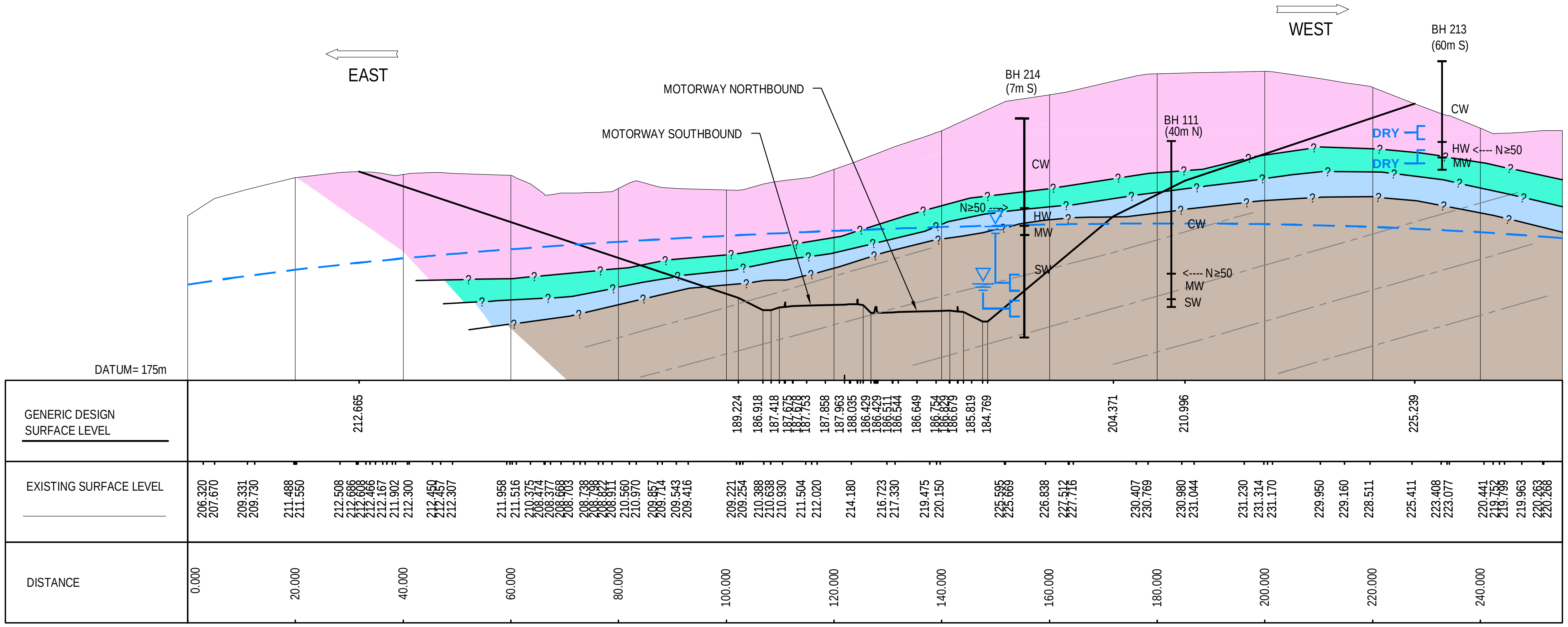
NOTES

1. GENERAL BEDDING DIP AND DIP DIRECTION (MEASURED BY OPTICAL TELEVIEWER): BH214 = 35°/ 137
2. VARIABLE JOINT SETS - DIP AND DIP DIRECTION: BH214 = 30°/ 193, 33°/ 086
3. APPARENT DIP OF BEDDING SHOWN ON CROSS SECTION. (APPARENT DIP IS DEFINED AS THE DIP OF A PLANE AS SEEN IN AN OBLIQUE SECTION)
4. REFER TO DRAWING GT-208 FOR SIGNIFICANT GEOTECHNICAL FEATURES



LOCALITY PLAN

0 25 50 75 100 125m
SCALE 1:5,000 @ A3 SIZE



CROSS SECTION AT CH 56550 (MCS0) - MOIRS HILL NORTH

HORIZONTAL SCALE 1:1000 @ A3
VERTICAL SCALE 1:1000 @ A3

0 5 10 15 20 25m
SCALE 1:1,000 @ A3 SIZE

AMD	DATE	DESIGN REVIEW	REV'D D. MGR	APP'D A. MGR	PURPOSE OF ISSUE / AMENDMENT
0	30/08/13	DJW	MRH	TI	ISSUED FOR NOR / CONSENT

FURTHER NORTH

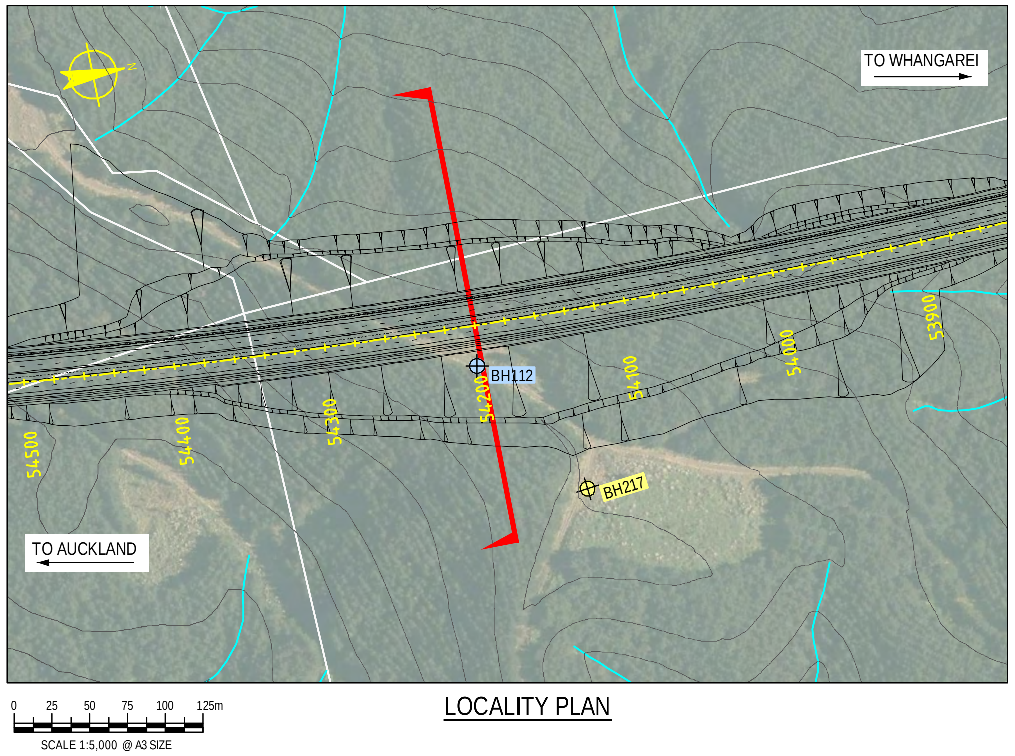
DISCLAIMER
The information shown on this drawing is solely for the purposes of supporting RMA applications for statutory approvals.
All information shown is subject to review for compliance with approved consents and the outcomes of final design.

ARA TŪHONO - PŪHOI TO WELLSFORD
PŪHOI TO WARKWORTH - FOR RMA APPROVALS

DRAWN	DRAFTING CHECK	REVIEWED DISCIPLINE MANAGER	APPROVED ALLIANCE MANAGER
SNP	DJW	MRH	TI
DESIGNED: RGK	DESIGN REVIEW: DJW		

GEOLOGICAL CROSS SECTIONS
CUTTINGS - SHEET 3 OF 4
MOIRS HILL NORTH CUTTING

SCALE	CONTRACT No	DRAWING No	AMDT
AS SHOWN	PA3748	GT-233	0



LOCALITY PLAN

NOTES

1. GENERAL BEDDING DIP AND DIP DIRECTION (MEASURED BY OPTICAL TELEVIEWER): BH 217 - 08°/ 274
   BH 112 - 06°/ 328
2. VARIABLE JOINT SETS - DIP AND DIP DIRECTION:
   BH 217 - 59°/ 335
   BH 112 - 74°/ 139, 30°/ 180
3. APPARENT DIP OF BEDDING SHOWN ON CROSS SECTION (APPARENT DIP IS DEFINED AS THE DIP OF A PLANE AS SEEN IN AN OBLIQUE SECTION)
4. REFER TO DRAWING GT-210 FOR SIGNIFICANT GEOTECHNICAL FEATURES

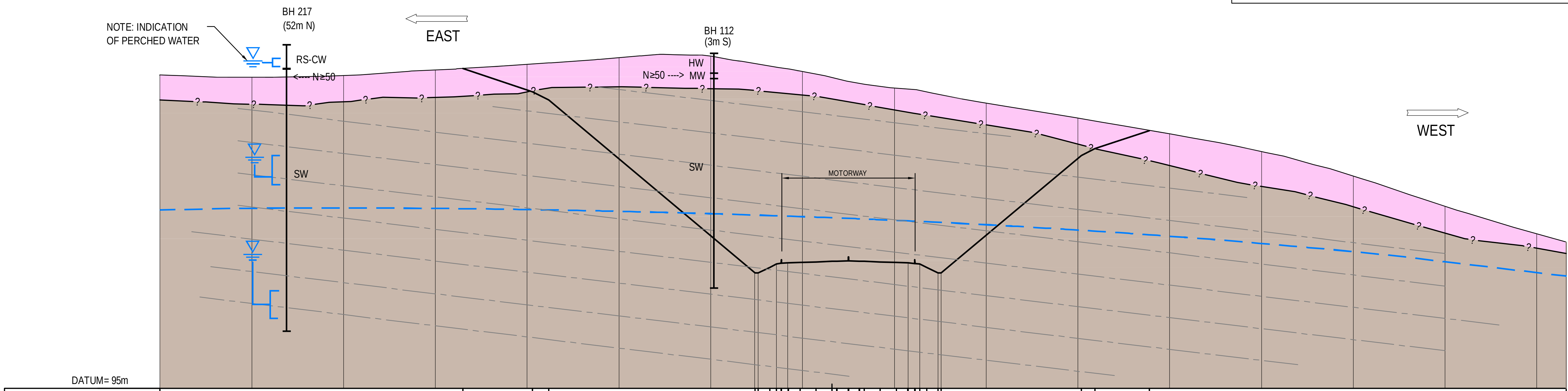
KEY

COLLUVIUM
ALLUVIUM

WAITEMATA GROUP (PAKIRI FORMATION):
- RS-CW (RESIDUAL SOIL TO COMPLETELY WEATHERED)
- HW (HIGHLY WEATHERED)
- MW (MODERATELY WEATHERED)
- SW (SLIGHTLY WEATHERED TO UNWEATHERED)

BOREHOLE
(5m W) OFFSET / DIRECTION FROM SECTION
RS-CW
HW
MW
SW
MEASURED PIEZOMETRIC READING ----------------->
PIEZOMETER - SCREEN INTERVAL ----------------->
<----- N≥50 SPT N VALUES ≥50 BELOW THIS DEPTH

INFERRED SHEAR ZONE
INFERRED GEOLOGICAL BOUNDARY
INFERRED GROUND WATER LEVEL (FROM HYDROGEOLOGICAL MODEL)
INFERRED APPARENT BEDDING (SPACING NOT TO SCALE)
INDICATIVE DESIGN SURFACE LEVEL



GENERIC DESIGN SURFACE LEVEL	164.680, 159.639, 157.865, 120.148, 120.148, 122.148, 122.405, 122.408, 122.483, 122.588, 122.693, 122.726, 122.798, 122.720, 122.687, 122.582, 122.477, 122.402, 122.252, 121.392, 120.142, 120.142, 145.761, 147.247, 151.195
EXISTING SURFACE LEVEL	163.200, 163.105, 162.799, 162.798, 162.736, 162.759, 162.928, 162.971, 163.287, 163.362, 164.033, 164.084, 164.576, 164.600, 165.069, 165.231, 165.236, 165.869, 165.904, 166.580, 166.665, 167.383, 167.501, 167.788, 167.756, 167.663, 167.610, 167.614, 167.298, 166.530, 166.196, 164.868, 164.506, 163.127, 161.950, 161.234, 161.146, 160.478, 160.076, 159.297, 158.056, 157.379, 156.291, 155.678, 154.736, 154.002, 153.057, 152.192, 151.325, 150.405, 149.552, 148.514, 147.733, 146.381, 145.563, 143.760, 142.869, 140.645, 139.707, 137.225, 136.351, 133.829, 133.103, 130.646, 130.078, 127.714, 126.864
DISTANCE	0.000, 20.000, 40.000, 60.000, 80.000, 100.000, 120.000, 140.000, 160.000, 180.000, 200.000, 220.000, 240.000, 260.000, 280.000, 300.000

CROSS SECTION AT CH 54200 (MCS0) - REDWOODS ROAD

HORIZONTAL SCALE 1:1000 @ A3
VERTICAL SCALE 1:1000 @ A3

0 5 10 15 20 25m
SCALE 1:1,000 @ A3 SIZE

AMD	DATE	DESIGN REVIEW	REV'D D. MGR	APP'D A. MGR	PURPOSE OF ISSUE / AMENDMENT
0	30/08/13	DJW	MRH	TI	ISSUED FOR NOR / CONSENT

FURTHER NORTH

DISCLAIMER
The information shown on this drawing is solely for the purposes of supporting RMA applications for statutory approvals. All information shown is subject to review for compliance with approved consents and the outcomes of final design.

ARA TŪHONO - PŪHOI TO WELLSFORD
PŪHOI TO WARKWORTH - FOR RMA APPROVALS

DRAWN	DRAFTING CHECK	REVIEWED DISCIPLINE MANAGER	APPROVED ALLIANCE MANAGER
SNP	DJW	MRH	TI
DESIGNED: RGK	DESIGN REVIEW: DJW		

GEOLOGICAL CROSS SECTIONS
CUTTINGS - SHEET 4 OF 4
REDWOODS ROAD CUTTING

SCALE	CONTRACT No	DRAWING No	AMDT
AS SHOWN	PA3748	GT-234	0

S:\Further North - PAA\300 Design\300.5 Technical\01-Drawing Production\CADD\Drawings\GT-231_GT-234.dwg Plot Date: 29 August, 2013 - 3:42 PM

Appendix G. Geological Cross Sections – Key Landslides

KEY

- COLLUVIUM
- ALLUVIUM
- WAITEMATA GROUP (PAKIRI FORMATION)
  - RS-CW (RESIDUAL SOIL TO COMPLETELY WEATHERED)
  - HW (HIGHLY WEATHERED)
  - MW (MODERATELY WEATHERED)
  - SW (SLIGHTLY WEATHERED TO UNWEATHERED)

MEASURED PIEZOMETRIC READING ---------------->

PIEZOMETER - SCREEN INTERVAL ---------------->

BOREHOLE (5m W) OFFSET / DIRECTION

RS-CW

HW

MW <----- N≥50 SPT N VALUES ≥50 BELOW THIS DEPTH

SW

INFERRED SHEAR ZONE

INFERRED GEOLOGICAL BOUNDARY

INFERRED GROUND WATER LEVEL (FROM HYDROGEOLOGICAL MODEL)

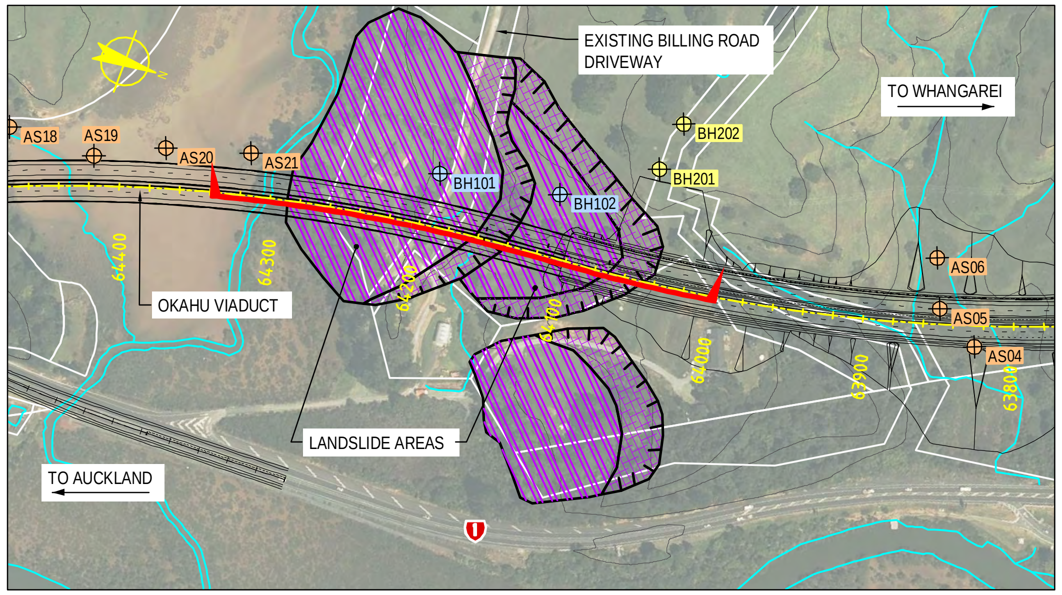
INFERRED APPARENT BEDDING (SPACING NOT TO SCALE)

INDICATIVE DESIGN SURFACE LEVEL

INDICATIVE LOCATION OF STRUCTURE (BRIDGE / VIADUCT)

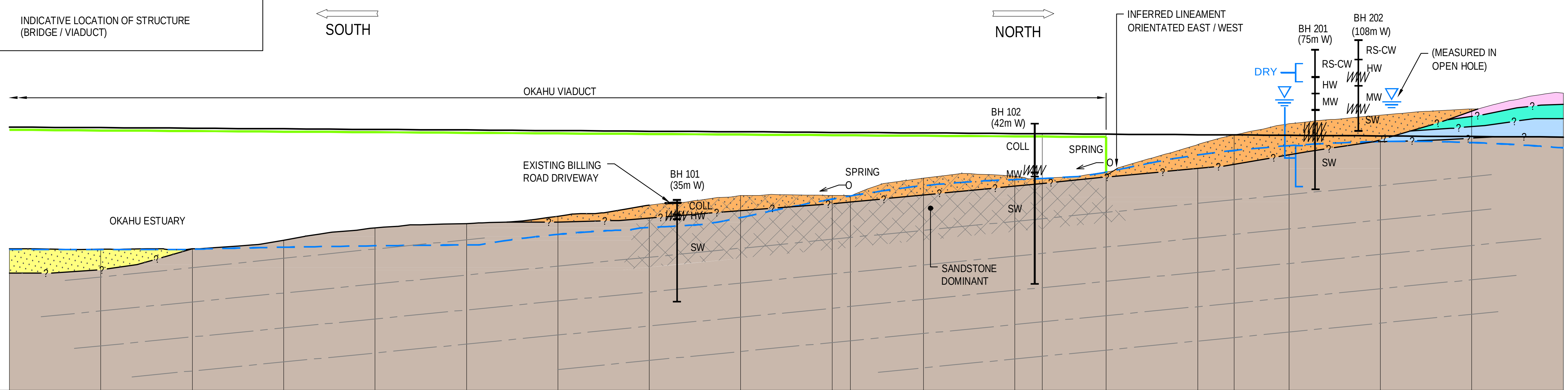
NOTES

1. GENERAL BEDDING DIP AND DIP DIRECTION BELOW LANDSLIDE MASS (MEASURED BY OPTICAL TELEVIEWER) : BH101 = 05°/ 180
   BH102 = 05°/ 104
   BH201 = 06°/ 186
   BH202 = 06°/ 180
2. APPARENT DIP OF BEDDING SHOWN ON CROSS SECTION (APPARENT DIP IS DEFINED AS THE DIP OF A PLANE AS SEEN IN AN OBLIQUE SECTION)
3. VARIABLE JOINT SETS - DIP AND DIP DIRECTIONS :
   BH101 = 20°/ 087, 51°/ 352
   BH12 = 16°/ 093, 60°/ 155
   BH201 = 73°/ 009, 76°/ 072, 32°/ 099, 79°/ 183, 62°/ 338
   BH202 = 75°/ 021, 21°/ 176
4. REFER TO DRAWING GT-202 FOR SIGNIFICANT GEOTECHNICAL FEATURES



LOCALITY PLAN

0 25 50 75 100 125m
SCALE 1:5,000 @ A3 SIZE



DESIGN SURFACE LEVEL	27.578	27.448	27.319	27.189	27.059	26.930	26.800	26.670	26.541	26.411		26.282	26.152		26.022	25.893		25.763	25.633	25.504	25.374
EXISTING SURFACE LEVEL	0.858	0.790	0.865	2.746	5.475	6.434	8.046	10.430	12.535	12.609		16.370	16.770		17.746	23.751		28.294	30.184	31.518	34.979
CHAINAGE	64340.000	64320.000	64300.000	64280.000	64260.000	64240.000	64220.000	64200.000	64180.000	64160.000	64155.975	64140.000	64120.000	64113.975	64100.000	64080.000	64071.975	64060.000	64040.000	64020.000	64000.000

LONGITUDINAL SECTION ON SOUTHBOUND ALIGNMENT (MCS0) AT BILLING ROAD

HORIZONTAL SCALE 1:1000 @ A3

VERTICAL SCALE 1:1000 @ A3

CH 64340 TO CH 64000

0 5 10 15 20 25m
SCALE 1:1,000 @ A3 SIZE

AMD	DATE	DESIGN REVIEW	REV'D D. MGR	APP'D A. MGR	PURPOSE OF ISSUE / AMENDMENT
0	30/08/13	DJW	MRH	TI	ISSUED FOR NOR / CONSENT

FURTHER NORTH

DISCLAIMER
The information shown on this drawing is solely for the purposes of supporting RMA applications for statutory approvals.
All information shown is subject to review for compliance with approved consents and the outcomes of final design.

ARA TŪHONO - PŪHOI TO WELLSFORD

PŪHOI TO WARKWORTH - FOR RMA APPROVALS

DRAWN	DRAFTING CHECK	REVIEWED DISCIPLINE MANAGER	APPROVED ALLIANCE MANAGER
SNP	DJW	MRH	TI
DESIGNED RGK	DESIGN REVIEW DJW		

GEOLOGICAL CROSS SECTIONS
EXISTING LANDSLIDES - SHEET 1 OF 7
BILLING ROAD

SCALE	CONTRACT No	DRAWING No	AMDT
AS SHOWN	PA3748	GT-311	0

S:\Further North - PAA\300 Design\300.5 Technical\01-Drawing Production\CADD\Drawings\GT-311_GT-316.dwg Plot Date: 11 September, 2013 - 10:47 AM

KEY

COLLUVIUM
ALLUVIUM

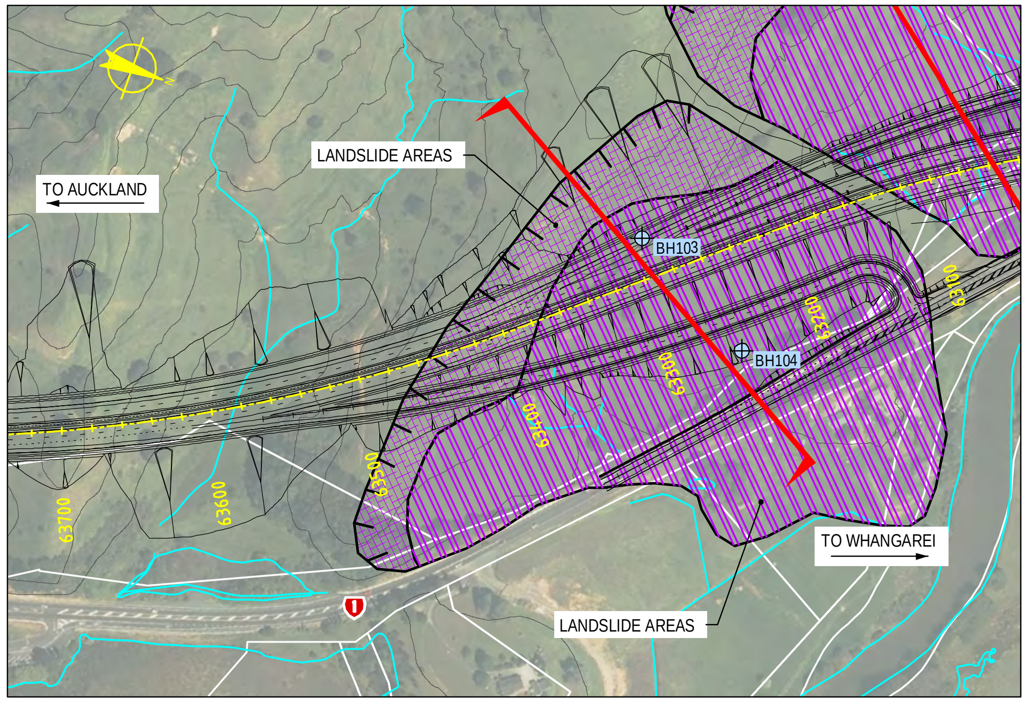
WAITEMATA GROUP (PAKIRI FORMATION)
- RS-CW (RESIDUAL SOIL TO COMPLETELY WEATHERED)
- HW (HIGHLY WEATHERED)
- MW (MODERATELY WEATHERED)
- SW (SLIGHTLY WEATHERED TO UNWEATHERED)

BOREHOLE (5m W) — OFFSET / DIRECTION
RS-CW
HW
MW
SW
MEASURED PIEZOMETRIC READING ---------------->
PIEZOMETER - SCREEN INTERVAL ---------------->
<----- N≥50 SPT N VALUES ≥50 BELOW THIS DEPTH

INFERRED SHEAR ZONE
INFERRED GEOLOGICAL BOUNDARY
INFERRED GROUND WATER LEVEL (FROM HYDROGEOLOGICAL MODEL)
INFERRED APPARENT BEDDING (SPACING NOT TO SCALE)
INDICATIVE DESIGN SURFACE LEVEL

NOTES

1. GENERAL BEDDING DIP AND DIP DIRECTION: BH 103 = 06°/ 032
   BH 104 = 03°/ 323
2. APPARENT DIP OF BEDDING SHOWN ON CROSS SECTION. (APPARENT DIP IS DEFINED AS THE DIP OF A PLANE AS SEEN IN AN OBLIQUE SECTION)
3. GENERAL SHEAR PLANE / COLLUVIUM CONTACT DIP AND DIP DIRECTION: 03°/ 012
4. VARIABLE JOINT SETS - DIP AND DIP DIRECTIONS:
   BH 103 = 73°/ 000, 70°/ 181, 81°/ 306
   BH 104 = 70°/ 301
5. REFER TO DRAWING GT-203 FOR SIGNIFICANT GEOTECHNICAL FEATURES

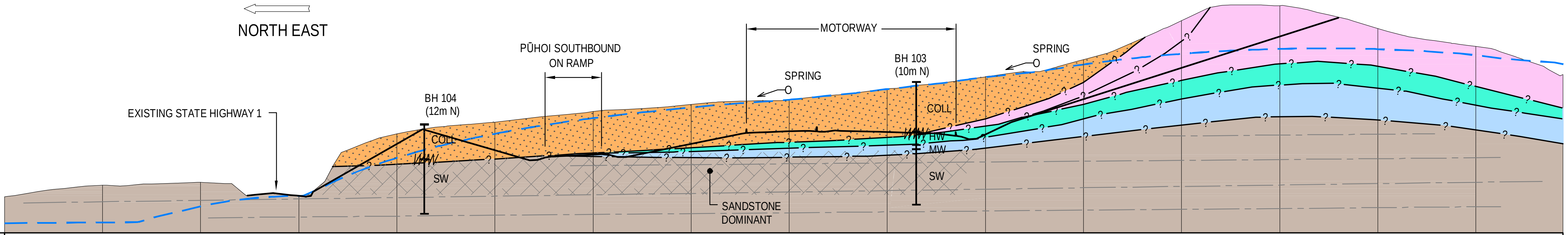


LOCALITY PLAN

0 25 50 75 100 125m
SCALE 1:5,000 @ A3 SIZE

SOUTH WEST

NORTH EAST



DESIGN SURFACE LEVEL: 7.617, 7.735, 8.055, 7.672, 7.390, 8.355, 21.136, 14.810, 15.372, 15.616, 15.794, 15.971, 15.895, 15.457, 20.222, 20.484, 20.568, 20.681, 20.794, 20.690, 20.645, 20.812, 20.715, 20.611, 20.473, 20.374, 20.302, 19.739, 19.135, 19.139, 22.582, 43.874

DISTANCE	0.000	20.000	40.000	60.000	80.000	100.000	120.000	140.000	160.000	180.000	200.000	220.000	240.000	260.000	280.000	300.000	317.764
EXISTING SURFACE LEVEL	7.340	9.663	10.269	7.520	20.164	22.603	24.736	26.209	27.156	29.407	31.855	35.362	43.304	46.396	41.716	38.045	32.316

CROSS SECTION - PŪHOI SOUTHBOUND ON RAMP

HORIZONTAL SCALE 1:1000 @ A3
VERTICAL SCALE 1:1000 @ A3

CH 63290

0 5 10 15 20 25m
SCALE 1:1,000 @ A3 SIZE

AMD	DATE	DESIGN REVIEW	REVD D. MGR	APPD A. MGR	PURPOSE OF ISSUE / AMENDMENT
0	30/08/13	DJW	MRH	TI	ISSUED FOR NOR / CONSENT

FURTHER NORTH

ARA TŪHONO - PŪHOI TO WELLSFORD

PŪHOI TO WARKWORTH - FOR RMA APPROVALS

DRAWN SNP | DRAFTING CHECK DJW | REVIEWED DISCIPLINE MANAGER MRH | APPROVED ALLIANCE MANAGER TI
DESIGNED RGK | DESIGN REVIEW DJW

GEOLOGICAL CROSS SECTIONS EXISTING LANDSLIDES - SHEET 2 OF 7 PŪHOI SOUTHBOUND ON RAMP

SCALE AS SHOWN | CONTRACT No PA3748 | DRAWING No GT-312 | AMDT 0

S:\Further North - PAA1300 Design\300.5 Technical\01-Drawing Production\CADD\Drawings\GT-311_GT-317.dwg Plot Date: 01 November , 2013 - 10:53 AM

KEY

COLLUVIUM
ALLUVIUM

WAITEMATA GROUP (PAKIRI FORMATION)
- RS-CW (RESIDUAL SOIL TO COMPLETELY WEATHERED)
- HW (HIGHLY WEATHERED)
- MW (MODERATELY WEATHERED)
- SW (SLIGHTLY WEATHERED TO UNWEATHERED)

MEASURED PIEZOMETRIC READING ---------------->

PIEZOMETER - SCREEN INTERVAL ---------------->

BOREHOLE (5m W) OFFSET / DIRECTION
RS-CW
HW
<----- N≥50 SPT N VALUES ≥50 BELOW THIS DEPTH
MW
SW

INFERRED SHEAR ZONE

INFERRED GEOLOGICAL BOUNDARY

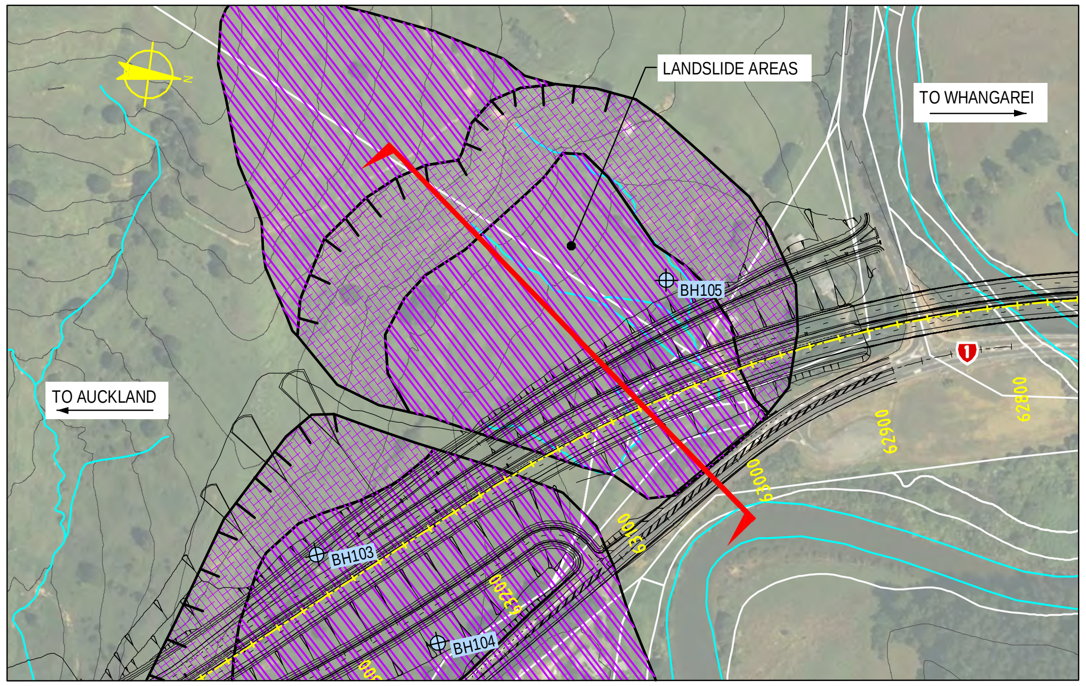
INFERRED GROUND WATER LEVEL (FROM HYDROGEOLOGICAL MODEL)

INFERRED APPARENT BEDDING (SPACING NOT TO SCALE)

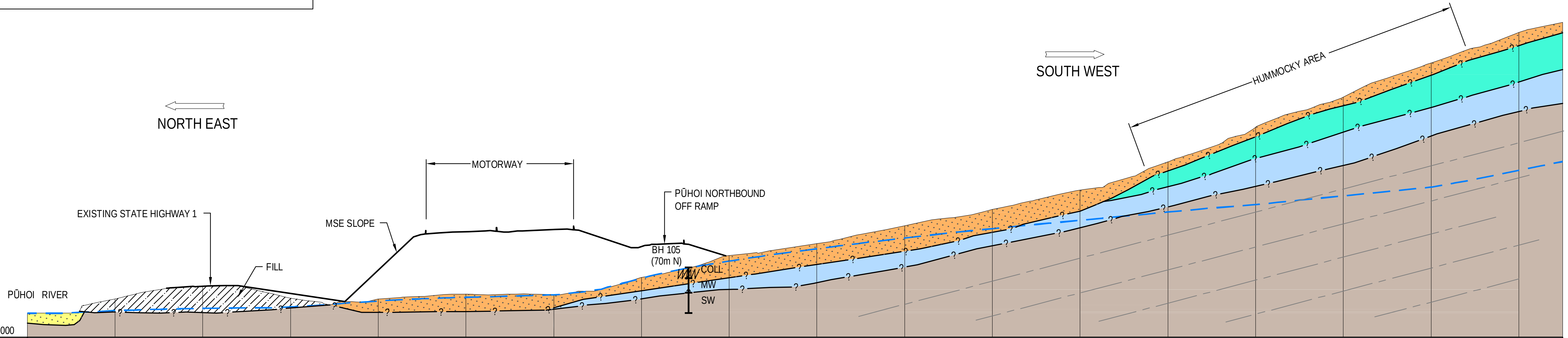
INDICATIVE DESIGN SURFACE LEVEL

NOTES

1. GENERAL BEDDING DIP AND DIP DIRECTION: BH105 = 19°/ 320
2. APPARENT DIP OF BEDDING SHOWN ON CROSS SECTION (APPARENT DIP IS DEFINED AS THE DIP OF A PLANE AS SEEN IN AN OBLIQUE SECTION)
3. GENERAL SHEAR PLANE / COLLUVIUM CONTACT AT 3m, DIP AND DIP DIRECTION: BH105 = 10°/ 314
4. VARIABLE JOINT SET - DIP AND DIP DIRECTION: BH105 = 57°/ 205
5. REFER TO DRAWING GT-203 FOR SIGNIFICANT GEOTECHNICAL FEATURES



LOCALITY PLAN



DESIGN SURFACE LEVEL: 6.215 6.367 6.604 6.550 6.738 6.789 6.766 6.809 3.169 17.913 18.529 18.526 18.857 18.963 19.111 19.260 19.165 19.027 19.268 19.416 19.564 19.523 19.416 15.412 15.937 16.218 16.352 16.197 15.709 13.533

EXISTING SURFACE LEVEL	0.498	3.784	6.719	3.955	3.743	4.879	4.739	8.661	13.671	16.353	20.435	24.132	28.539	34.982	42.876	49.725	57.490	64.414
DISTANCE	0.000	20.000	40.000	60.000	80.000	100.000	120.000	140.000	160.000	180.000	200.000	220.000	240.000	260.000	280.000	300.000	320.000	340.000

CROSS SECTION - PŪHOI NORTHBOUND OFF RAMP

CH 63055

HORIZONTAL SCALE 1:1000 @ A3
VERTICAL SCALE 1:1000 @ A3

0 5 10 15 20 25m
SCALE 1:1,000 @ A3 SIZE

AMD	DATE	DESIGN REVIEW	REVD D. MGR	APPD A. MGR	PURPOSE OF ISSUE / AMENDMENT
0	30/08/13	DJW	MRH	TI	ISSUED FOR NOR / CONSENT

FURTHER NORTH

ARA TŪHONO - PŪHOI TO WELLSFORD

PŪHOI TO WARKWORTH - FOR RMA APPROVALS

DRAWN SNP | DRAFTING CHECK DJW | REVIEWED DISCIPLINE MANAGER MRH | APPROVED ALLIANCE MANAGER TI
DESIGNED RGK | DESIGN REVIEW DJW

GEOLOGICAL CROSS SECTIONS EXISTING LANDSLIDES - SHEET 3 OF 7 PŪHOI NORTHBOUND OFF RAMP

SCALE AS SHOWN | CONTRACT No PA3748 | DRAWING No GT-313 | AMDT 0

S:\Further North - PAA\300 Design\300.5 Technical\01-Drawing Production\CADD\Drawings\GT-311_GT-317.dwg Plot Date: 01 November , 2013 - 10:54 AM

KEY

- COLLUVIUM
- ALLUVIUM

WAITEMATA GROUP (PAKIRI FORMATION)

- RS-CW (RESIDUAL SOIL TO COMPLETELY WEATHERED)
- HW (HIGHLY WEATHERED)
- MW (MODERATELY WEATHERED)
- SW (SLIGHTLY WEATHERED TO UNWEATHERED)

BOREHOLE

MEASURED PIEZOMETRIC READING ---------------->

(5m W) OFFSET / DIRECTION

RS-CW

HW

<----- N≥50 SPT N VALUES ≥50 BELOW THIS DEPTH

MW

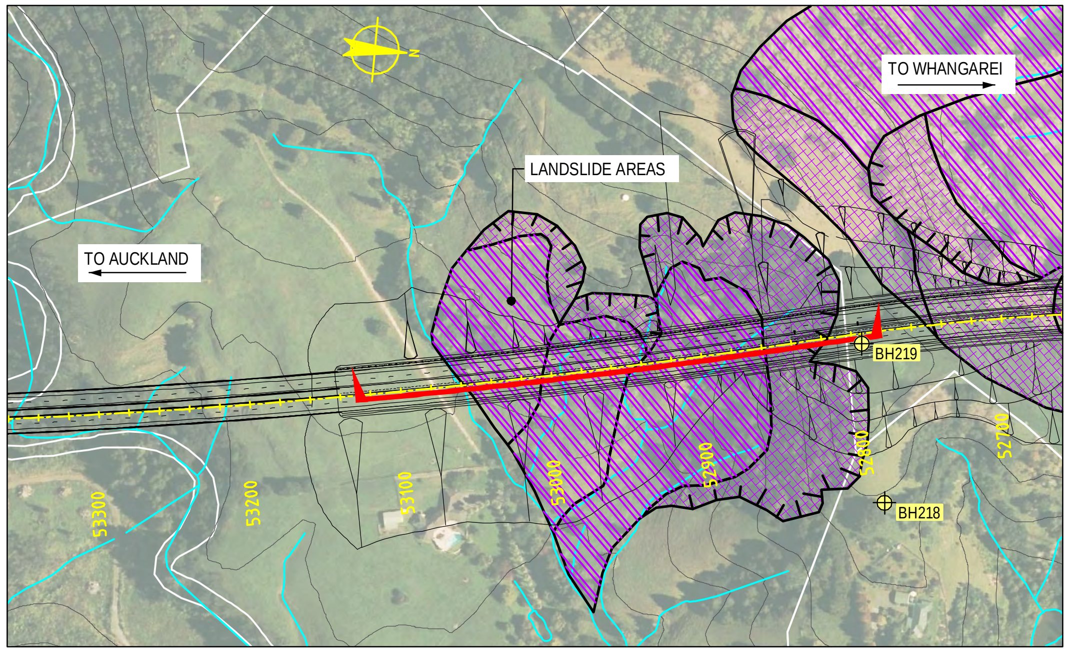
SW

PIEZOMETER - SCREEN INTERVAL ---------------->

- INFERRED SHEAR ZONE
- INFERRED GEOLOGICAL BOUNDARY
- INFERRED GROUND WATER LEVEL (FROM HYDROGEOLOGICAL MODEL)
- INFERRED APPARENT BEDDING (SPACING NOT TO SCALE)
- INDICATIVE DESIGN SURFACE LEVEL

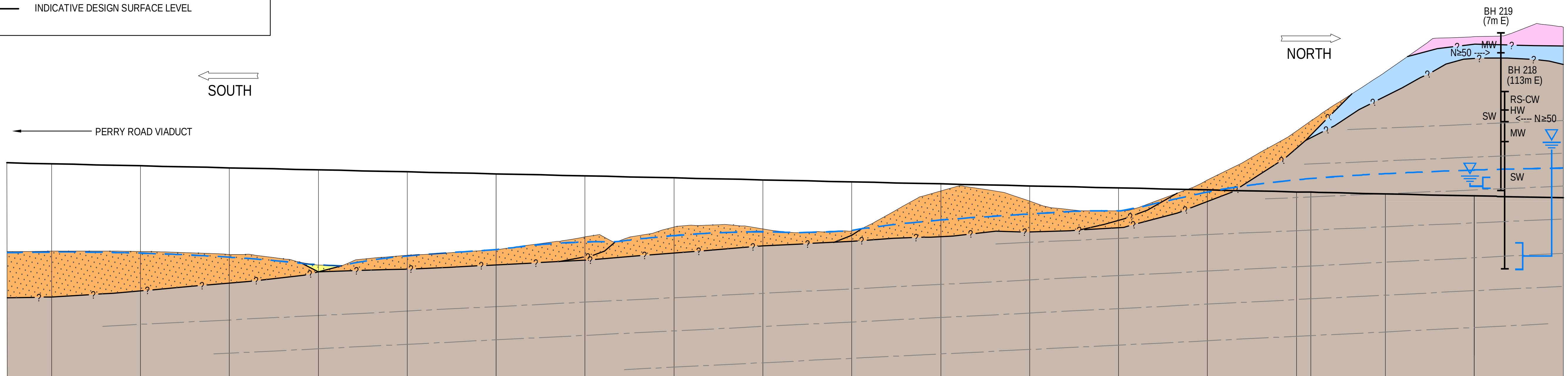
NOTES

1. GENERAL BEDDING DIP AND DIP DIRECTION: BH218 = 04°/ 234
2. APPARENT DIP OF BEDDING SHOWN ON CROSS SECTION (APPARENT DIP IS DEFINED AS THE DIP OF A PLANE AS SEEN IN AN OBLIQUE SECTION)
3. VARIABLE JOINT SETS - DIP AND DIP DIRECTIONS: BH218 = 60°/ 124, 60°/ 281, 34°/ 350
4. REFER TO DRAWINGS GT-210 & GT-211 FOR SIGNIFICANT GEOTECHNICAL FEATURES



LOCALITY PLAN

0 25 50 75 100 125m
SCALE 1:5,000 @ A3 SIZE



DESIGN SURFACE LEVEL	82.107	81.657	81.207	80.757	80.307	79.857	79.407	78.957	78.507	78.057	77.607	77.157	76.707	76.257	75.807	75.357	74.907	74.457
EXISTING SURFACE LEVEL	62.446	62.414	61.731	59.346	61.500	62.825	65.662	67.850	67.454	67.035	75.987	73.709	71.556	78.448	89.455	102.793	110.711	112.896
CHAINAGE	53120.000	53100.000	53080.000	53060.000	53040.000	53020.000	53000.000	52980.000	52960.000	52940.000	52920.000	52900.000	52880.000	52860.000	52840.000 52836.754	52820.000	52800.000 52800.000 52794.754	52780.000

LONGITUDINAL SECTION ON SOUTHBOUND ALIGNMENT (MCS0) - NORTH OF PERRY ROAD VIADUCT

CH 52780 TO CH 53120

HORIZONTAL SCALE 1:1000 @ A3
VERTICAL SCALE 1:1000 @ A3

0 5 10 15 20 25m
SCALE 1:1,000 @ A3 SIZE

AMD	DATE	DESIGN REVIEW	REV'D D. MGR	APP'D A. MGR	PURPOSE OF ISSUE / AMENDMENT
0	30/08/13	DJW	MRH	TI	ISSUED FOR NOR / CONSENT

FURTHER NORTH

DISCLAIMER
The information shown on this drawing is solely for the purposes of supporting RMA applications for statutory approvals.
All information shown is subject to review for compliance with approved consents and the outcomes of final design.

ARA TŪHONO - PŪHOI TO WELLSFORD

PŪHOI TO WARKWORTH - FOR RMA APPROVALS

DRAWN SNP | DRAFTING CHECK DJW | REVIEWED DISCIPLINE MANAGER MRH | APPROVED ALLIANCE MANAGER TI
DESIGNED RGK | DESIGN REVIEW DJW

GEOLOGICAL CROSS SECTIONS
EXISTING LANDSLIDES - SHEET 4 OF 7
PERRY ROAD

SCALE AS SHOWN | CONTRACT No PA3748 | DRAWING No GT-314 | AMDT 0

S:\Further North - PAA\300 Design\300.5 Technical\01-Drawing Production\CADD\Drawings\GT-311_GT-316.dwg Plot Date: 29 August , 2013 - 3:09 PM

KEY

- COLLUVIUM
- ALLUVIUM
- WAITEMATA GROUP (PAKIRI FORMATION):
  - RS-CW (RESIDUAL SOIL TO COMPLETELY WEATHERED)
  - HW (HIGHLY WEATHERED)
  - MW (MODERATELY WEATHERED)
  - SW (SLIGHTLY WEATHERED TO UNWEATHERED)

MEASURED PIEZOMETRIC READING ----------------->

PIEZOMETER - SCREEN INTERVAL ----------------->

BOREHOLE (5m W) — OFFSET / DIRECTION

RS-CW

HW

<----- N≥50 — SPT N VALUES ≥50 BELOW THIS DEPTH

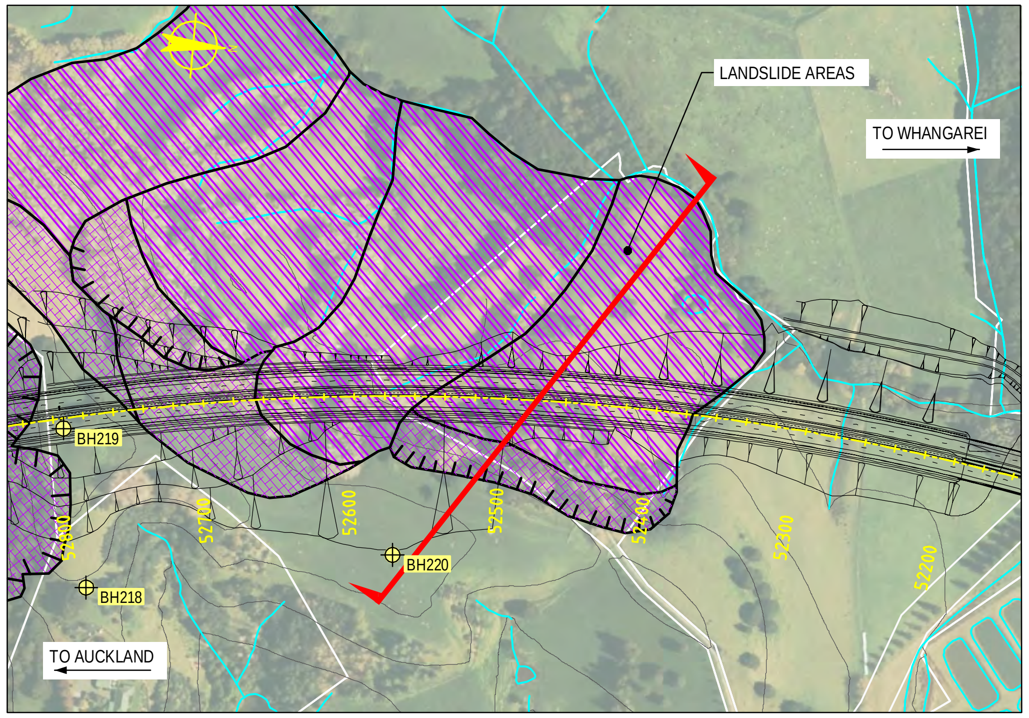
MW

SW

- INFERRED SHEAR ZONE
- INFERRED GEOLOGICAL BOUNDARY
- INFERRED GROUND WATER LEVEL (FROM HYDROGEOLOGICAL MODEL)
- INFERRED APPARENT BEDDING (SPACING NOT TO SCALE)
- INDICATIVE DESIGN SURFACE LEVEL

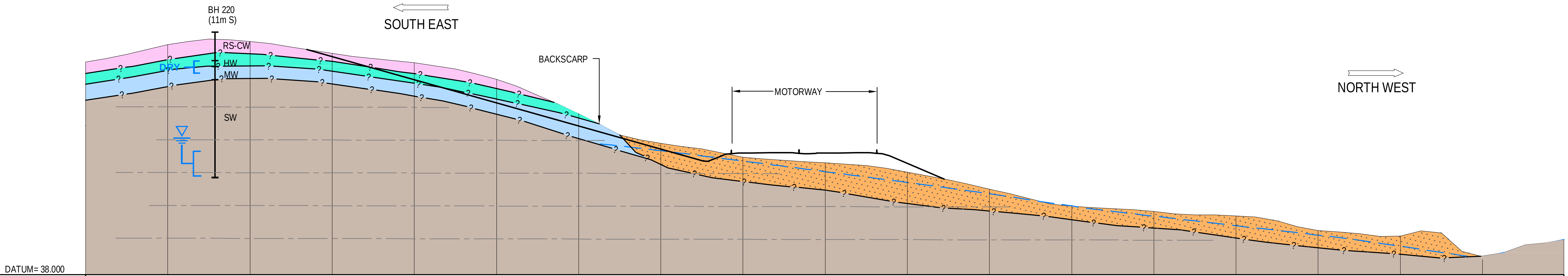
NOTES

1. GENERAL BEDDING DIP AND DIP DIRECTION: BH220 = 06°/ 170
2. APPARENT DIP OF BEDDING SHOWN ON CROSS SECTION (APPARENT DIP IS DEFINED AS THE DIP OF A PLANE AS SEEN IN AN OBLIQUE SECTION)
3. VARIABLE JOINT SETS - DIP AND DIP DIRECTIONS: DOMINANT SETS OF NORTHWEST AND WEST ORIENTATION
4. REFER TO DRAWING GT-211 FOR SIGNIFICANT GEOTECHNICAL FEATURES



LOCALITY PLAN

0 25 50 75 100 125m
SCALE 1:5,000 @ A3 SIZE



DESIGN SURFACE LEVEL	92.804	65.612	65.597	67.339	67.556	67.558	67.593	67.642	67.692	67.544	67.422	67.546	67.561	67.611	67.662	67.698	67.523	66.875	61.241

EXISTING SURFACE LEVEL	89.790	93.998	94.716	91.877	89.558	85.561	77.191	69.941	66.598	65.180	62.973	58.819	54.678	53.346	52.285	48.679	47.320	41.627	46.531
DISTANCE	0.000	20.000	40.000	60.000	80.000	100.000	120.000	140.000	160.000	180.000	200.000	220.000	240.000	260.000	280.000	300.000	320.000	340.000	359.804

CROSS SECTION - SOUTH OF KAURI ECO VIADUCT

CH 52500

HORIZONTAL SCALE 1:1000 @ A3
VERTICAL SCALE 1:1000 @ A3

0 5 10 15 20 25m
SCALE 1:1,000 @ A3 SIZE

AMD	DATE	DESIGN REVIEW	REV'D D. MGR	APP'D A. MGR	PURPOSE OF ISSUE / AMENDMENT
0	30/08/13	DJW	MRH	TI	ISSUED FOR NOR / CONSENT

FURTHER NORTH

ARA TŪHONO - PŪHOI TO WELLSFORD

PŪHOI TO WARKWORTH - FOR RMA APPROVALS

DRAWN	DRAFTING CHECK	REVIEWED DISCIPLINE MANAGER	APPROVED ALLIANCE MANAGER
SNP	DJW	MRH	TI
DESIGNED: RGK	DESIGN REVIEW: DJW		

GEOLOGICAL CROSS SECTIONS
EXISTING LANDSLIDES - SHEET 5 OF 7
SOUTH OF KAURI ECO VIADUCT

SCALE	CONTRACT No	DRAWING No	AMDT
AS SHOWN	PA3748	GT-315	0

KEY

- COLLUVIUM
- ALLUVIUM

WAITEMATA GROUP (PAKIRI FORMATION)
- RS-CW (RESIDUAL SOIL TO COMPLETELY WEATHERED)
- HW (HIGHLY WEATHERED)
- MW (MODERATELY WEATHERED)
- SW (SLIGHTLY WEATHERED TO UNWEATHERED)

BOREHOLE (5m W) — OFFSET / DIRECTION

MEASURED PIEZOMETRIC READING ---------------->

RS-CW

HW

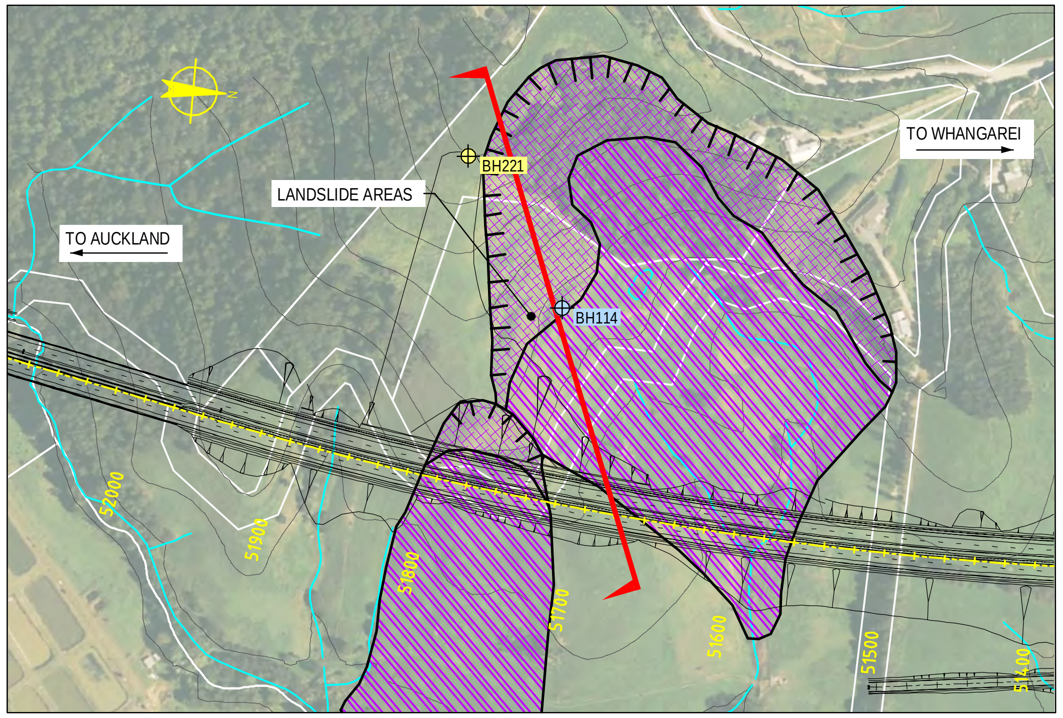
<----- N≥50 — SPT N VALUES ≥50 BELOW THIS DEPTH

MW

PIEZOMETER - SCREEN INTERVAL ---------------->

SW

- INFERRED SHEAR ZONE
- INFERRED GEOLOGICAL BOUNDARY
- INFERRED GROUND WATER LEVEL (FROM HYDROGEOLOGICAL MODEL)
- INFERRED APPARENT BEDDING (SPACING NOT TO SCALE)
- INDICATIVE DESIGN SURFACE LEVEL



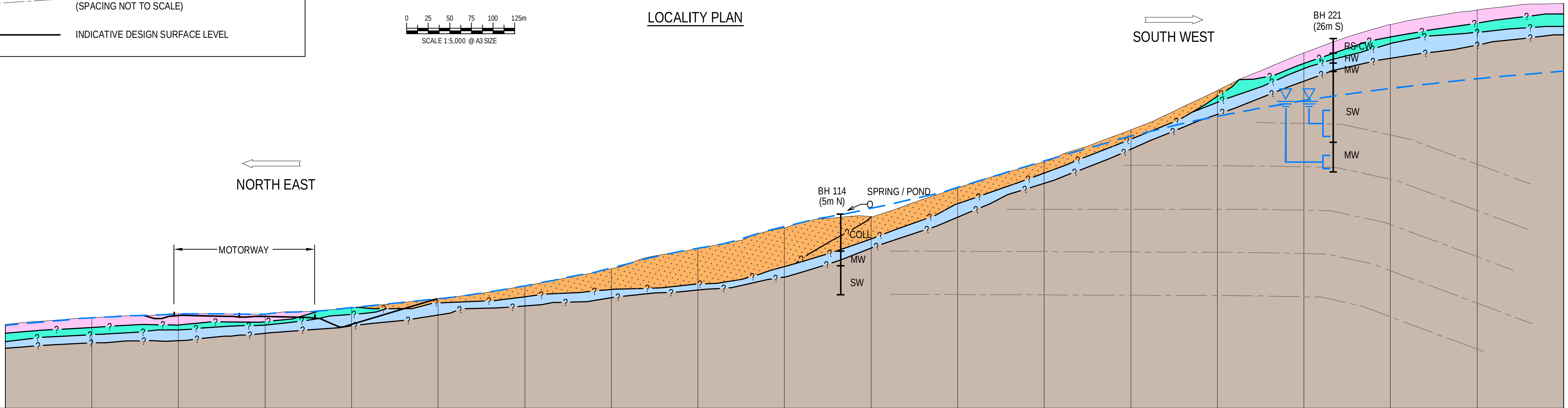
0 25 50 75 100 125m

SCALE 1:5,000 @ A3 SIZE

LOCALITY PLAN

NOTES

1. GENERAL BEDDING DIP AND DIP DIRECTION: BH 221 = 05°/ 233,
   BH 114 = 15°/ 011
2. APPARENT DIP OF BEDDING SHOWN ON CROSS SECTION (APPARENT DIP IS DEFINED AS THE DIP OF A PLANE AS SEEN IN AN OBLIQUE SECTION)
3. GENERAL SHEAR PLANE / COLLUVIUM CONTACT DIP AND DIP DIRECTION: 11°/ 042
4. VARIABLE JOINT SETS - DIP AND DIP DIRECTIONS:
   BH 114 = 63°/ 010, 59°/ 105
   BH 221 - 66°/ 086, 50°/ 182
5. REFER TO DRAWING GT-211 FOR SIGNIFICANT GEOTECHNICAL FEATURES



DESIGN SURFACE LEVEL	56.457, 55.698, 56.318, 56.474, 56.409, 56.318, 56.227, 56.067, 56.045, 56.240, 56.149, 56.058, 55.991, 55.744, 55.000, 53.763, 60.298
EXISTING SURFACE LEVEL	54.340, 55.919, 56.791, 56.773, 58.235, 60.328, 63.277, 67.200, 71.903, 76.724, 79.230, 85.929, 91.977, 99.334, 108.416, 117.073, 123.653, 126.978, 128.512
DISTANCE	0.000, 20.000, 40.000, 60.000, 80.000, 100.000, 120.000, 140.000, 160.000, 180.000, 200.000, 220.000, 240.000, 260.000, 280.000, 300.000, 320.000, 340.000, 360.000

CROSS SECTION - WYLLIE ROAD

HORIZONTAL SCALE 1:1000 @ A3

VERTICAL SCALE 1:1000 @ A3

CH 51680

0 5 10 15 20 25m

SCALE 1:1,000 @ A3 SIZE

AMD	DATE	DESIGN REVIEW	REVD D. MGR	APPD A. MGR	PURPOSE OF ISSUE / AMENDMENT
0	30/08/13	DJW	MRH	TI	ISSUED FOR NOR / CONSENT

FURTHER NORTH

DISCLAIMER

The information shown on this drawing is solely for the purposes of supporting RMA applications for statutory approvals. All information shown is subject to review for compliance with approved consents and the outcomes of final design.

ARA TŪHONO - PŪHOI TO WELLSFORD

PŪHOI TO WARKWORTH - FOR RMA APPROVALS

DRAWN	DRAFTING CHECK	REVIEWED DISCIPLINE MANAGER	APPROVED ALLIANCE MANAGER
SNP	DJW	MRH	TI
DESIGNED: RGK	DESIGN REVIEW: DJW		

GEOLOGICAL CROSS SECTIONS
EXISTING LANDSLIDES - SHEET 6 OF 7
WYLLIE ROAD

SCALE	CONTRACT No	DRAWING No	AMDT
AS SHOWN	PA3748	GT-316	0

S:\Further North - PAA1300 Design\300.5 Technical\01-Drawing Production\CADD\Drawings\GT-311_GT-317.dwg Plot Date: 01 November , 2013 - 10:16 AM

KEY

- COLLUVIUM
- ALLUVIUM

WAITEMATA GROUP (PAKIRI FORMATION)
- RS-CW (RESIDUAL SOIL TO COMPLETELY WEATHERED)
- HW (HIGHLY WEATHERED)
- MW (MODERATELY WEATHERED)
- SW (SLIGHTLY WEATHERED TO UNWEATHERED)

BOREHOLE (5m W) — OFFSET / DIRECTION
RS-CW
HW
<----- N≥50 — SPT N VALUES ≥50 BELOW THIS DEPTH
MW
SW

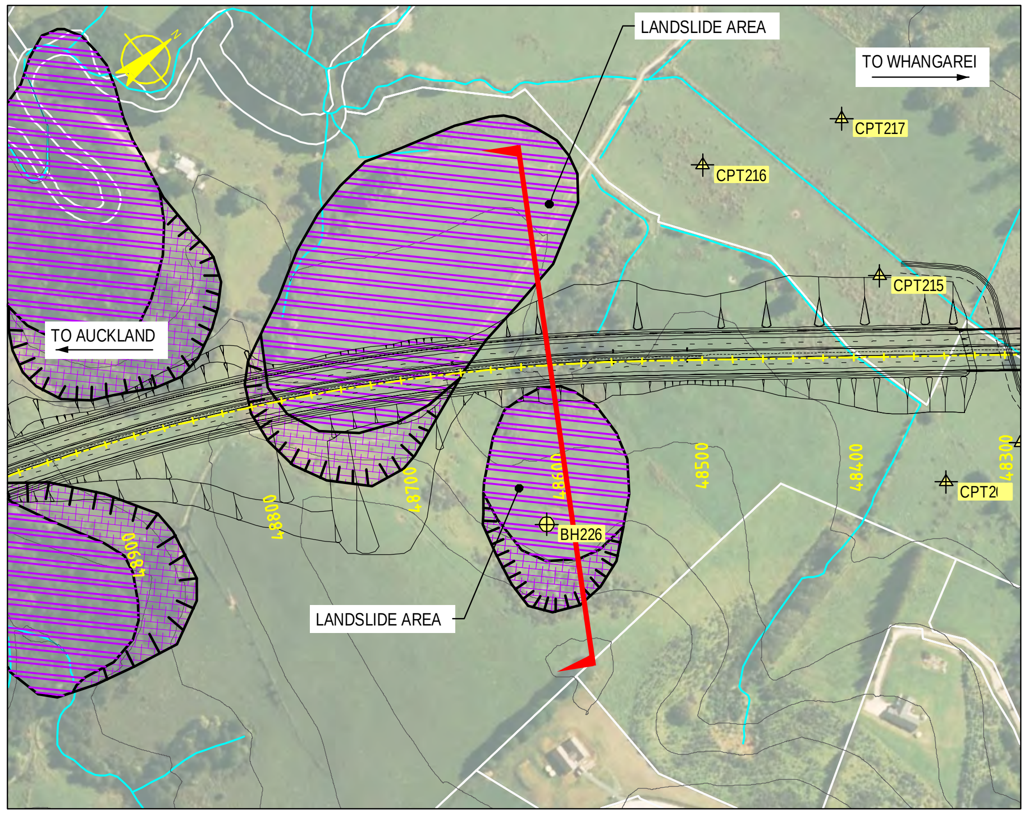
MEASURED PIEZOMETRIC READING ---------------->

PIEZOMETER - SCREEN INTERVAL ---------------->

- INFERRED SHEAR ZONE
- INFERRED GEOLOGICAL BOUNDARY
- INFERRED GROUND WATER LEVEL (FROM HYDROGEOLOGICAL MODEL)
- INFERRED APPARENT BEDDING (SPACING NOT TO SCALE)
- INDICATIVE DESIGN SURFACE LEVEL

NOTES

1. GENERAL BEDDING DIP AND DIP DIRECTION: BH226 = 42°/ 272
2. APPARENT DIP OF BEDDING SHOWN ON CROSS SECTION (APPARENT DIP IS DEFINED AS THE DIP OF A PLANE AS SEEN IN AN OBLIQUE SECTION)
3. GENERAL SHEAR PLANE / COLLUVIUM CONTACT DIP AND DIP DIRECTION: 66.°/ 319 AT 12.9m DEPTH
4. REFER TO DRAWING GT-214 FOR SIGNIFICANT GEOTECHNICAL FEATURES.

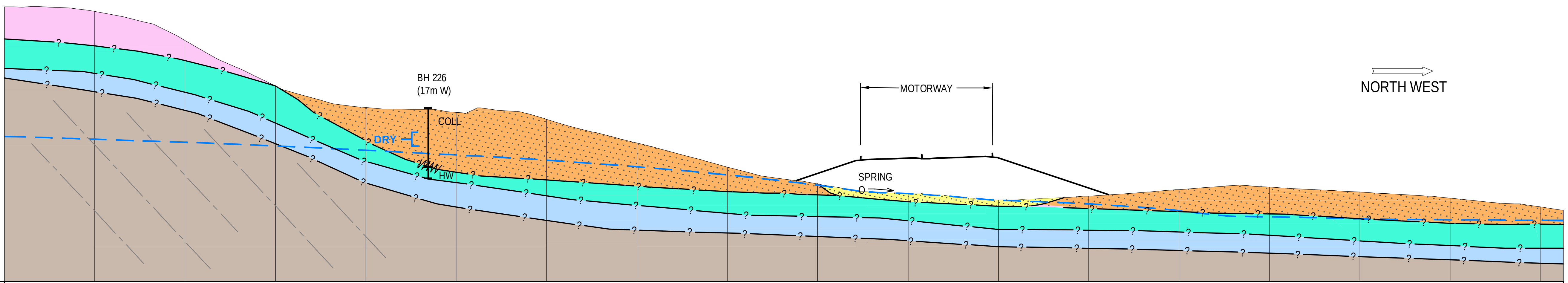


LOCALITY PLAN

0 25 50 75 100 125m
SCALE 1:5,000 @ A3 SIZE

SOUTH EAST

NORTH WEST



DESIGN SURFACE LEVEL										46.706 46.963	47.309 47.274	47.620 47.357						
EXISTING SURFACE LEVEL	80.742	79.696	73.281	63.185	58.460	57.386	55.863	50.640	45.310	41.544	39.458	38.013	38.879	40.303	40.845	39.729	38.421	36.454
DISTANCE	40.000	60.000	80.000	100.000	120.000	140.000	160.000	180.000	200.000	220.000	240.000	260.000	280.000	300.000	320.000	340.000	360.000	380.000

CROSS SECTION - CARRAN ROAD

HORIZONTAL SCALE 1:1000 @ A3
VERTICAL SCALE 1:1000 @ A3

CH 48600

0 5 10 15 20 25m
SCALE 1:1,000 @ A3 SIZE

AMD	DATE	DESIGN REVIEW	REVD D. MGR	APPD A. MGR	PURPOSE OF ISSUE / AMENDMENT
0	30/08/13	DJW	MRH	TI	ISSUED FOR NOR / CONSENT

FURTHER NORTH

DISCLAIMER
The information shown on this drawing is solely for the purposes of supporting RMA applications for statutory approvals. All information shown is subject to review for compliance with approved consents and the outcomes of final design.

ARA TŪHONO - PŪHOI TO WELLSFORD
PŪHOI TO WARKWORTH - FOR RMA APPROVALS

DRAWN	DRAFTING CHECK	REVIEWED DISCIPLINE MANAGER	APPROVED ALLIANCE MANAGER
SNP	DJW	MRH	TI
DESIGNED RGK	DESIGN REVIEW DJW		

GEOLOGICAL CROSS SECTIONS
EXISTING LANDSLIDES - SHEET 7 OF 7
CARRAN ROAD

SCALE	CONTRACT No	DRAWING No	AMDT
AS SHOWN	PA3748	GT-317	0

S:\Further North - PAA1300 Design\300.5 Technical\01-Drawing Production\CADD\Drawings\GT-311_GT-317.dwg   Plot Date: 01 November , 2013 - 10:55 AM

Appendix H. Typical Geotechnical Design Drawings

GT-241 Embankment and Spoil Disposal - Shear Key & Under Drainage - Typical Plan and Longitudinal Section

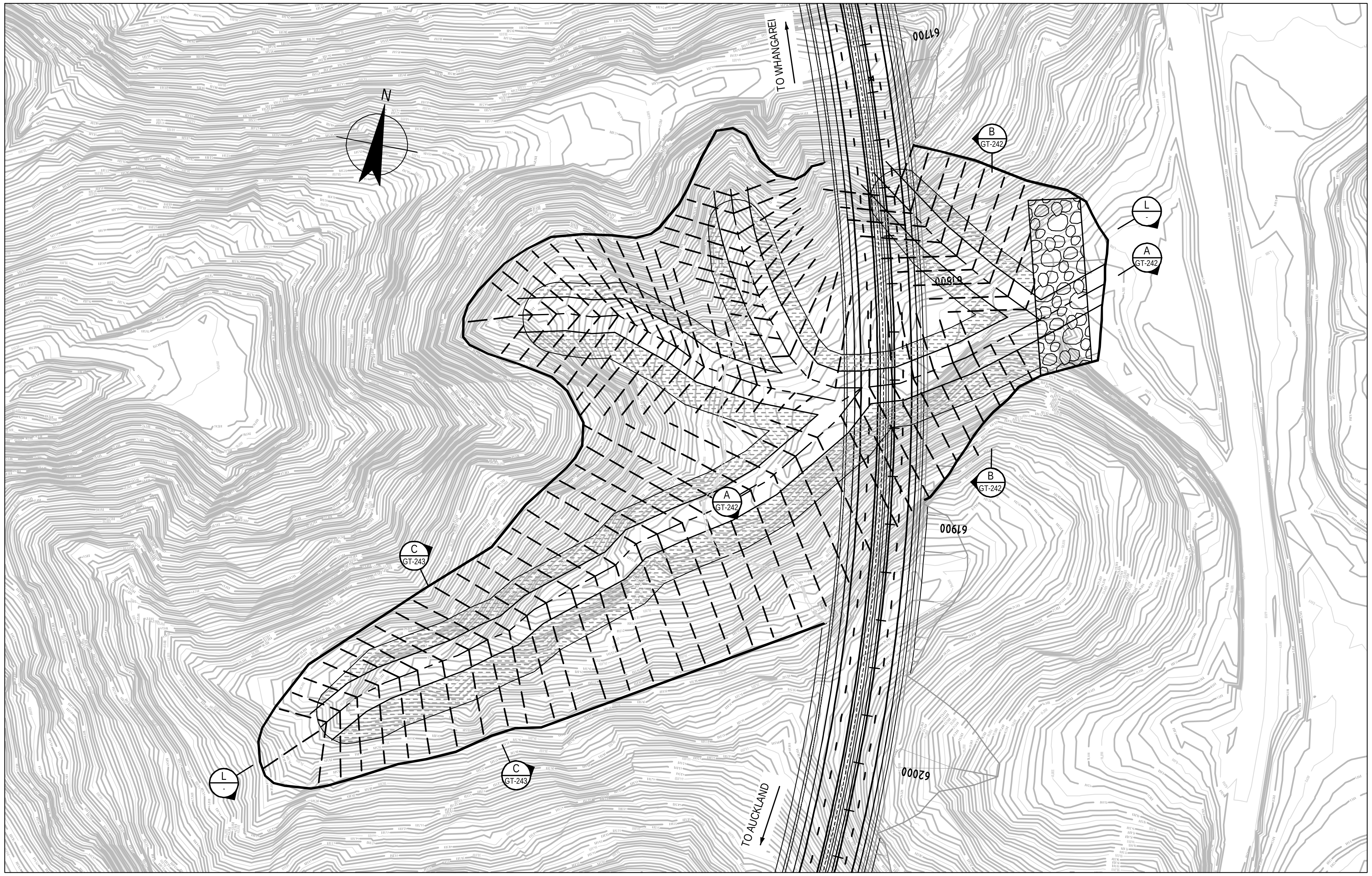
GT-242 Embankment and Spoil Disposal - Shear Key & Under Drainage - TypicalDetails

GT-243 Embankment and Spoil Disposal - Gully & Underfill Drain - Typical Detail

GT-244 Spoil Disposal Plan - Spoil Site SL 10 Concept Design - Plan and Section Details

GT-301 Conceptual Landslide Treatment Options - Sheet 1 of 2

GT-302 Conceptual Landslide Treatment Options - Sheet 2 of 2



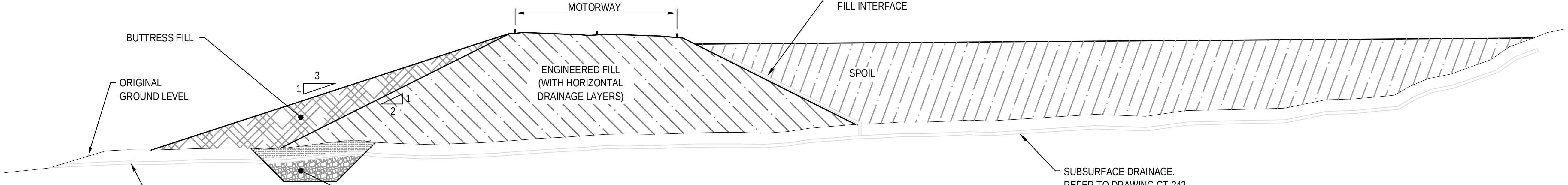
PLAN
NOT TO SCALE

KEY

- EXTENT OF EARTHWORKS
- EXTENT OF ENGINEERED EMBANKMENT FILL BENEATH SPOIL
- GULLY DRAIN
- PIPED UNDERFILL DRAINS
- SHEAR KEY
- UNDERCUT

NOTES

1. GULLY DRAIN TO BE SET OUT ON SITE TO FOLLOW LOW POINT OF GULLY
2. GENERALLY THE UPPER END OF ALL UNDERFILL DRAINS TO END AT 5m WITHIN THE TOE OF THE FILL UNLESS SHOWN OTHERWISE ON THE DRAWINGS
3. GENERALLY UNDERFILL DRAINS SETOUT AT 10m CENTRES
4. MINIMUM UNDRAINED SHEAR STRENGTH AT BASE OF UNDERCUTS TO BE 80kPa



L TYPICAL LONGITUDINAL SECTION L-L
NOT TO SCALE

AMD	DATE	DESIGN REVIEW	REVD D. MGR	APPD A. MGR	PURPOSE OF ISSUE / AMENDMENT
0	30/08/13	DJW	MRH	TI	ISSUED FOR NOR / CONSENT

FURTHER NORTH

DISCLAIMER
The information shown on this drawing is solely for the purposes of supporting RMA applications for statutory approvals. All information shown is subject to review for compliance with approved consents and the outcomes of final design.

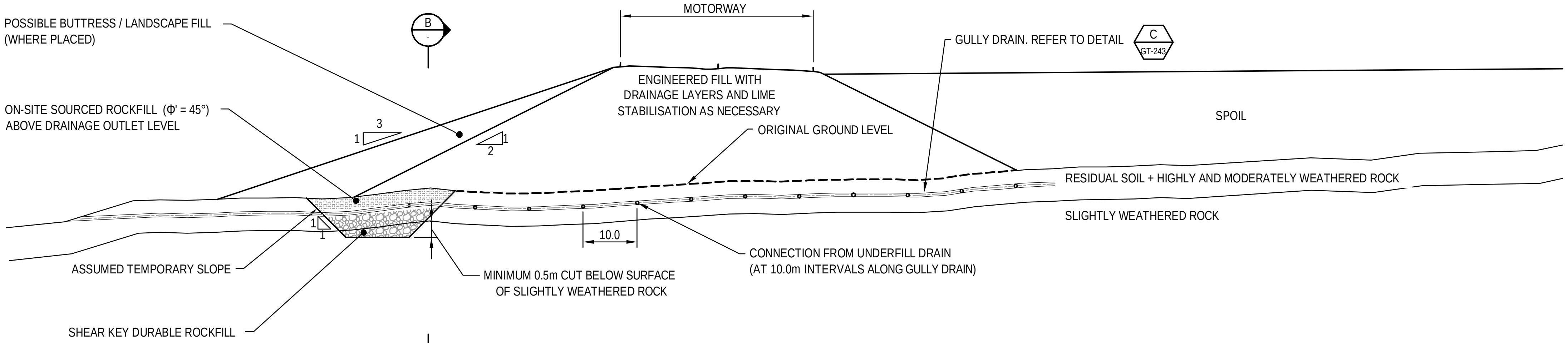
ARA TŪHONO - PŪHOI TO WELLSFORD
PŪHOI TO WARKWORTH - FOR RMA APPROVALS

DRAWN	DRAFTING CHECK	REVIEWED DISCIPLINE MANAGER	APPROVED ALLIANCE MANAGER
SP / AN	OJH	MRH	TI
DESIGNED: OJH	DESIGN REVIEW: DJW		

EMBANKMENT AND SPOIL DISPOSAL
SHEAR KEY AND UNDER DRAINAGE
TYPICAL PLAN AND LONGITUDINAL SECTION

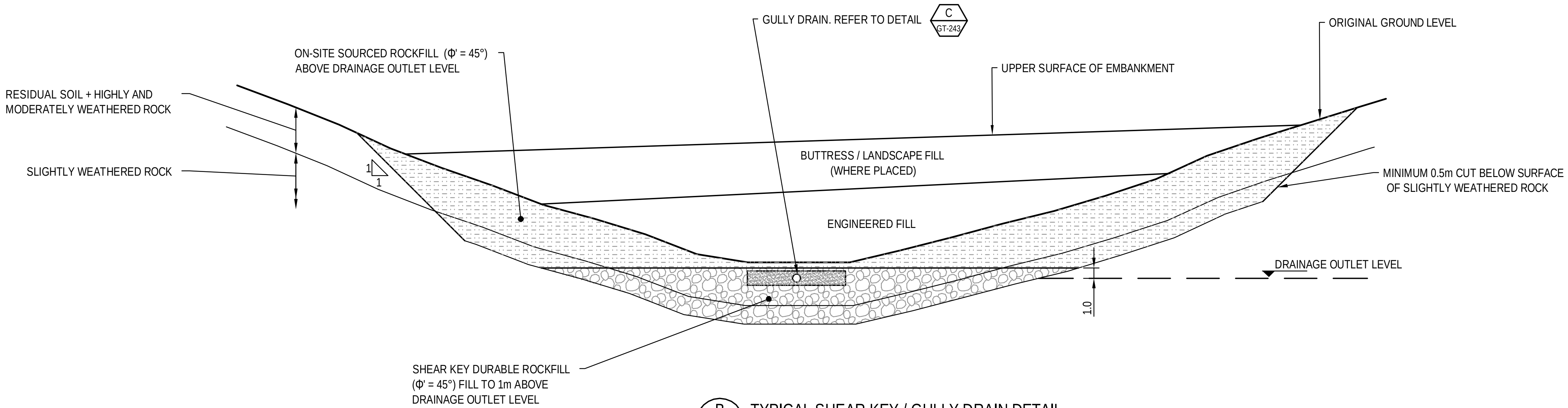
SCALE	CONTRACT No	DRAWING No	AMDT
NOT TO SCALE	PA3748	GT-241	0

S:\Further North - PAA\300 Design\300.5 Technical\01-Drawing Production\CADD\Drawings\GT-241_GT-243.dwg Plot Date: 17 September, 2013 - 1:44 PM



A GT-241 **TYPICAL SHEAR KEY/GULLY DRAIN DETAIL**

NOT TO SCALE



B - **TYPICAL SHEAR KEY / GULLY DRAIN DETAIL**

NOT TO SCALE

AMD	DATE	DESIGN REVIEW	REV'D D. MGR	APP'D A. MGR	PURPOSE OF ISSUE / AMENDMENT
0	30/08/13	DJW	MRH	TI	ISSUED FOR NOR / CONSENT

FURTHER NORTH

DISCLAIMER
The information shown on this drawing is solely for the purposes of supporting RMA applications for statutory approvals.
All information shown is subject to review for compliance with approved consents and the outcomes of final design.

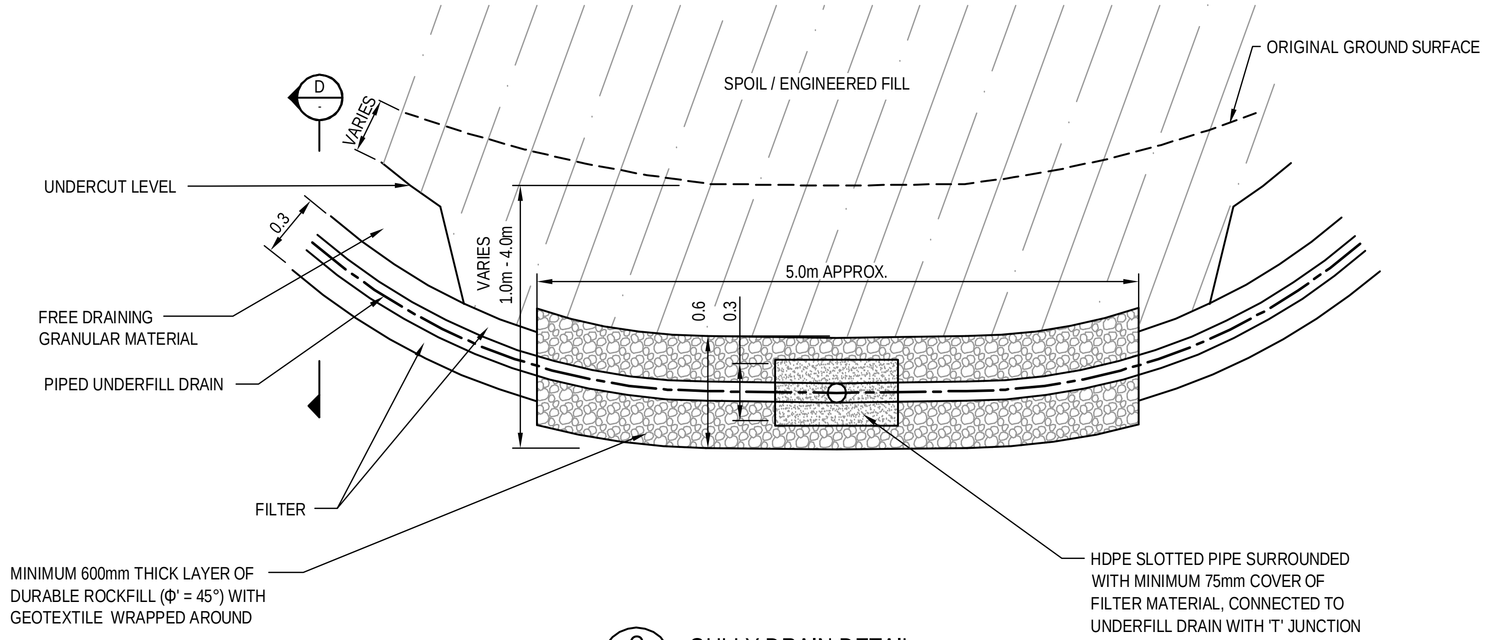
ARA TŪHONO - PŪHOI TO WELLSFORD

PŪHOI TO WARKWORTH - FOR RMA APPROVALS

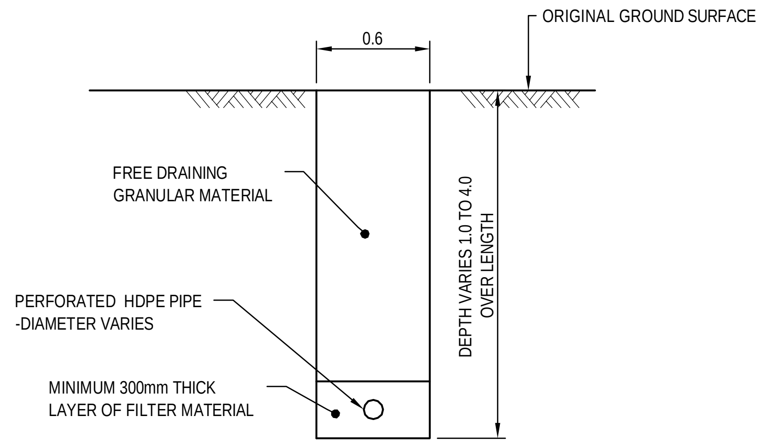
DRAWN	DRAFTING CHECK	REVIEWED DISCIPLINE MANAGER	APPROVED ALLIANCE MANAGER
SP/AN	OJH	MRH	TI
DESIGNED: OJH	DESIGN REVIEW: DJW		

EMBANKMENT AND SPOIL DISPOSAL
SHEAR KEY AND UNDER DRAINAGE
TYPICAL DETAILS

SCALE	CONTRACT No	DRAWING No	AMDT
NOT TO SCALE	PA3748	GT-242	0



C
GT-241
GULLY DRAIN DETAIL
NOT TO SCALE



D
-
PIPED UNDERFILL DRAIN DETAIL
NOT TO SCALE

AMD	DATE	DESIGN REVIEW	REV'D D. MGR	APP'D A. MGR	PURPOSE OF ISSUE / AMENDMENT
0	30/08/13	DJW	MRH	TI	ISSUED FOR NOR / CONSENT

FURTHER NORTH

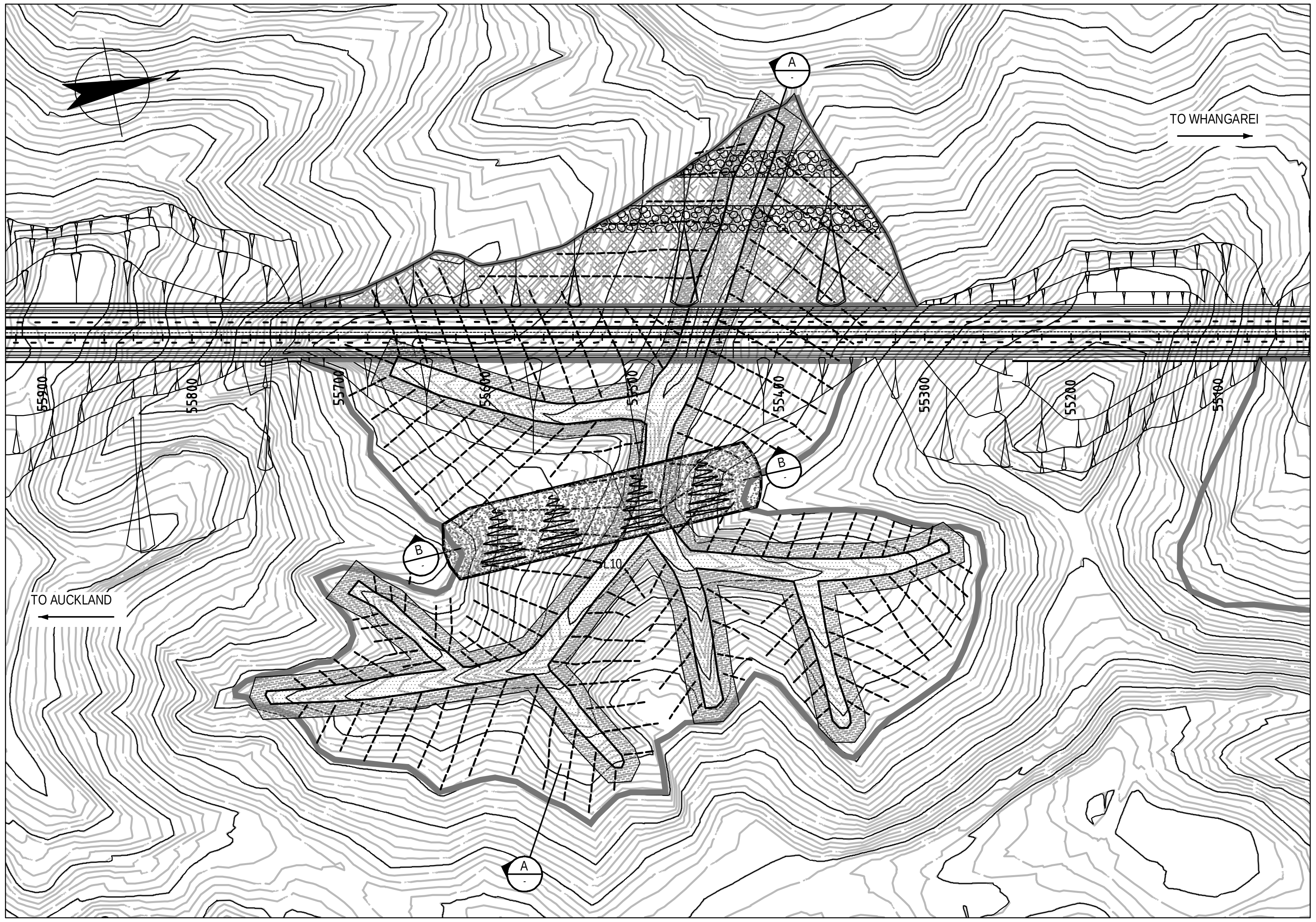
DISCLAIMER
The information shown on this drawing is solely for the purposes of supporting RMA applications for statutory approvals.
All information shown is subject to review for compliance with approved consents and the outcomes of final design.

ARA TŪHONO - PŪHOI TO WELLSFORD
PŪHOI TO WARKWORTH - FOR RMA APPROVALS

DRAWN	DRAFTING CHECK	REVIEWED DISCIPLINE MANAGER	APPROVED ALLIANCE MANAGER
SP/AN	OJH	MRH	TI
DESIGNED: OJH	DESIGN REVIEW: DJW		

EMBANKMENT AND SPOIL DISPOSAL
GULLY AND UNDERFILL DRAIN
TYPICAL DETAIL

SCALE	CONTRACT No	DRAWING No	AMDT
NOT TO SCALE	PA3748	GT-243	0



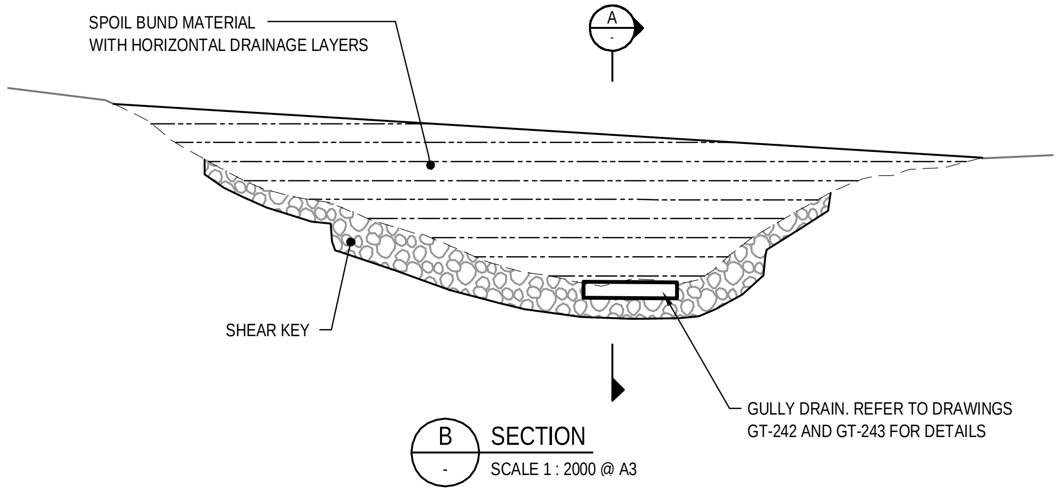
PLAN
SCALE 1:4000 @ A3

KEY

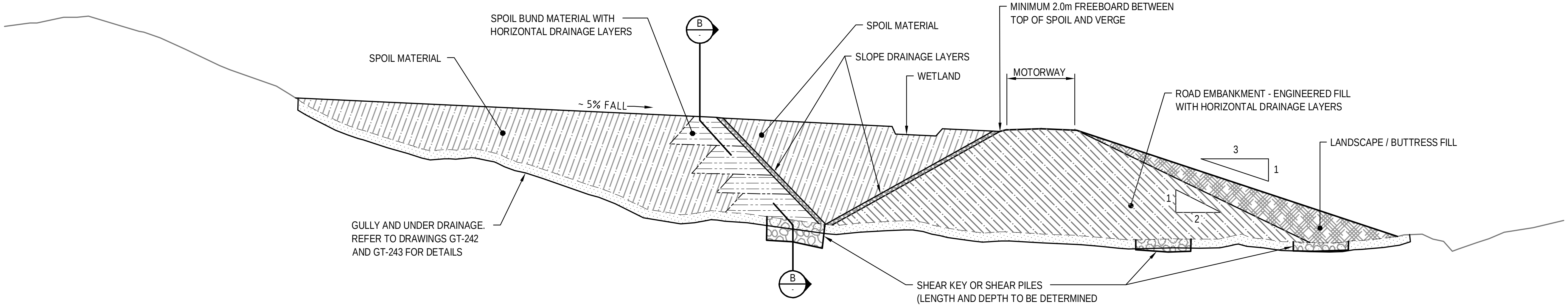
- SPOIL SITE SL10 OUTLINE
- ROAD EMBANKMENT LANDSCAPE FILL
- GULLY DRAIN
- UNDER DRAINS
- SPOIL BUND WITH SHEAR KEY
- SHEAR KEY
- UNDERCUT

NOTES

1. GULLY DRAIN TO BE SET OUT ON SITE TO FOLLOW LOW POINT OF GULLY
2. GENERALLY THE UPPER END OF ALL UNDERFILL DRAINS TO END AT 5m WITHIN THE TOE OF THE FILL UNLESS SHOWN OTHERWISE ON THE DRAWINGS
3. GENERALLY UNDERFILL DRAINS SETOUT AT 10m CENTRES
4. MINIMUM UNDRAINED SHEAR STRENGTH AT BASE OF UNDERCUTS TO BE 80kPa



B SECTION
SCALE 1 : 2000 @ A3



A SECTION
SCALE 1 : 2000 @ A3

0 10 20 30 40 50m
SCALE 1:2,000 @ A3 SIZE

0 20 40 60 80 100m
SCALE 1:4,000 @ A3 SIZE

AMD	DATE	DESIGN REVIEW	REVD D. MGR	APPD A. MGR	PURPOSE OF ISSUE / AMENDMENT
0	30/08/13	DJW	MRH	TI	ISSUED FOR NOR / CONSENT

FURTHER NORTH

DISCLAIMER
The information shown on this drawing is solely for the purposes of supporting RMA applications for statutory approvals. All information shown is subject to review for compliance with approved consents and the outcomes of final design.

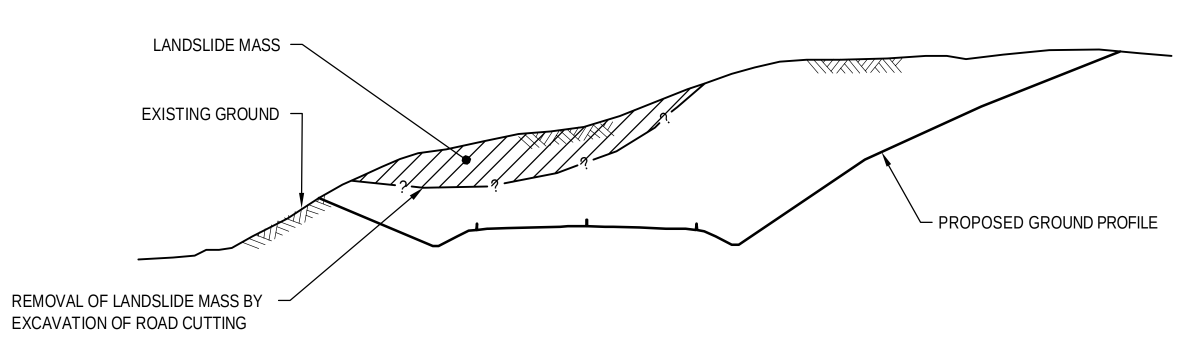
ARA TŪHONO - PŪHOI TO WELLSFORD
PŪHOI TO WARKWORTH - FOR RMA APPROVALS

DRAWN	DRAFTING CHECK	REVIEWED DISCIPLINE MANAGER	APPROVED ALLIANCE MANAGER
SP / AN	OJH	MRH	TI
DESIGNED OJH	DESIGN REVIEW DJW		

SPOIL DISPOSAL PLAN
SPOIL SITE SL10 - CONCEPT DESIGN
PLAN AND SECTION DETAILS

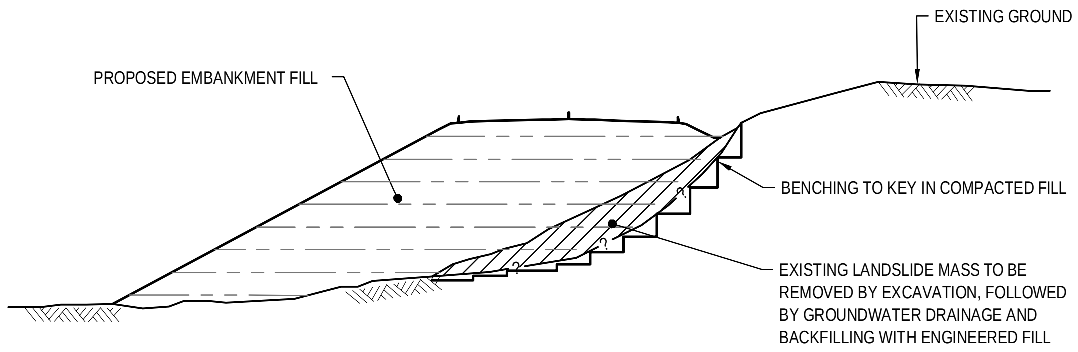
SCALE	CONTRACT No	DRAWING No	AMDT
AS SHOWN	PA3748	GT-244	0

S:\Further North - PAA\300 Design\300.5 Technical\01-Drawing Production\CADD\Drawings\GT-244.dwg Plot Date: 17 September , 2013 - 1:46 PM



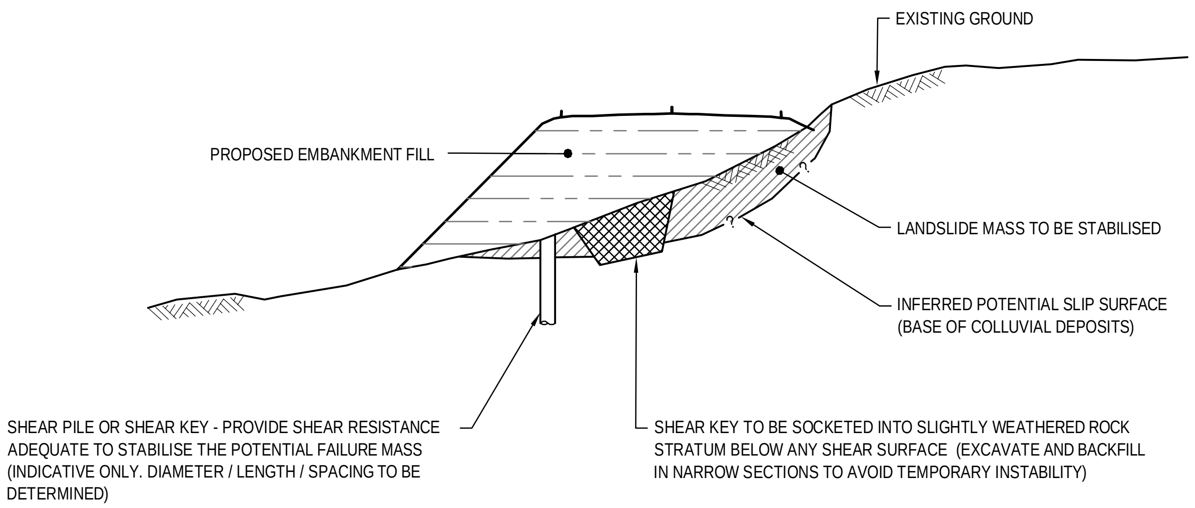
LANDSLIDE TREATMENT - TYPE 1

NOT TO SCALE



LANDSLIDE TREATMENT - TYPE 2

NOT TO SCALE

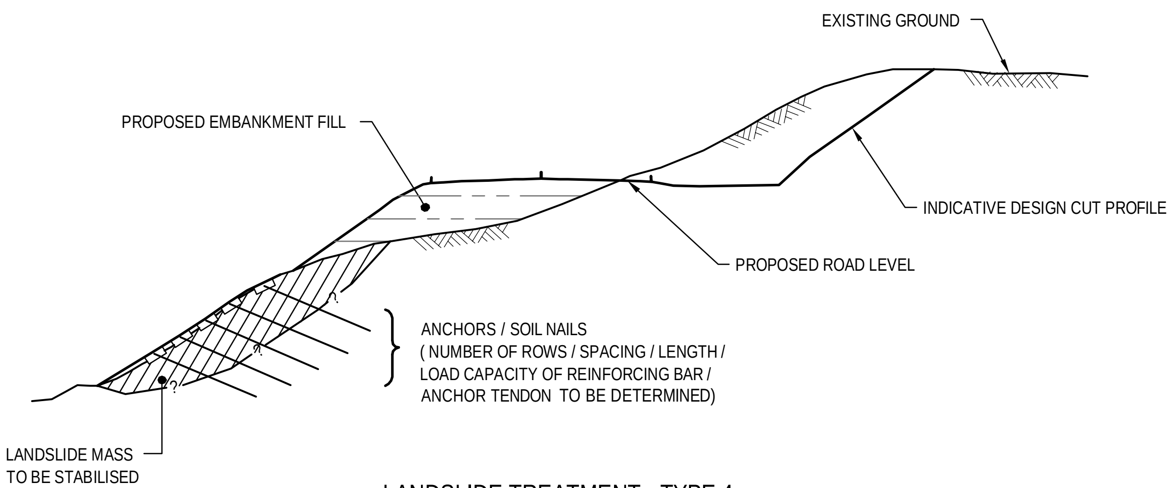


LANDSLIDE TREATMENT - TYPE 3

NOT TO SCALE

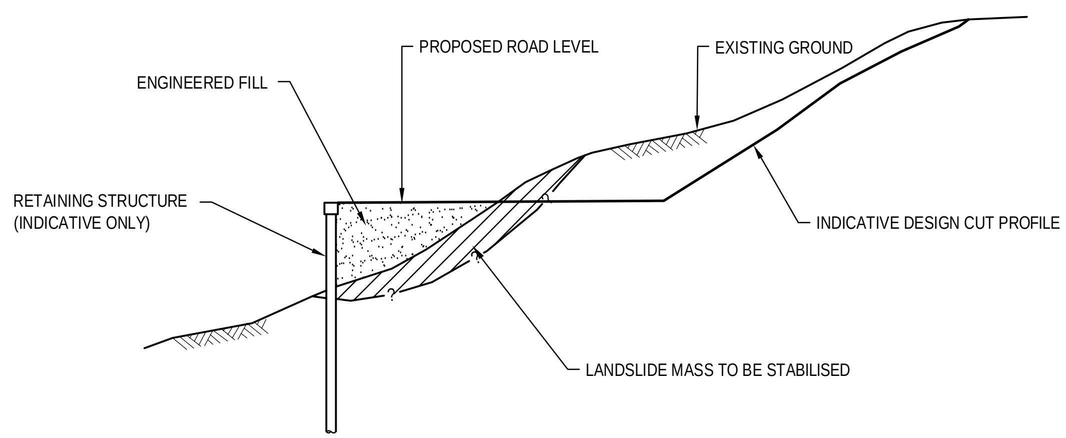
LEGEND

INTERPRETED LANDSLIDE MASS



LANDSLIDE TREATMENT - TYPE 4

NOT TO SCALE



LANDSLIDE TREATMENT - TYPE 5

NOT TO SCALE

AMD	DATE	DESIGN REVIEW	REVD D. MGR	APPD A. MGR	PURPOSE OF ISSUE / AMENDMENT
0	30/08/13	DJW	MRH	TI	ISSUE FOR NOR / CONSENT

FURTHER NORTH

DISCLAIMER

The information shown on this drawing is solely for the purposes of supporting RMA applications for statutory approvals. All information shown is subject to review for compliance with approved consents and the outcomes of final design.

ARA TŪHONO - PŪHOI TO WELLSFORD

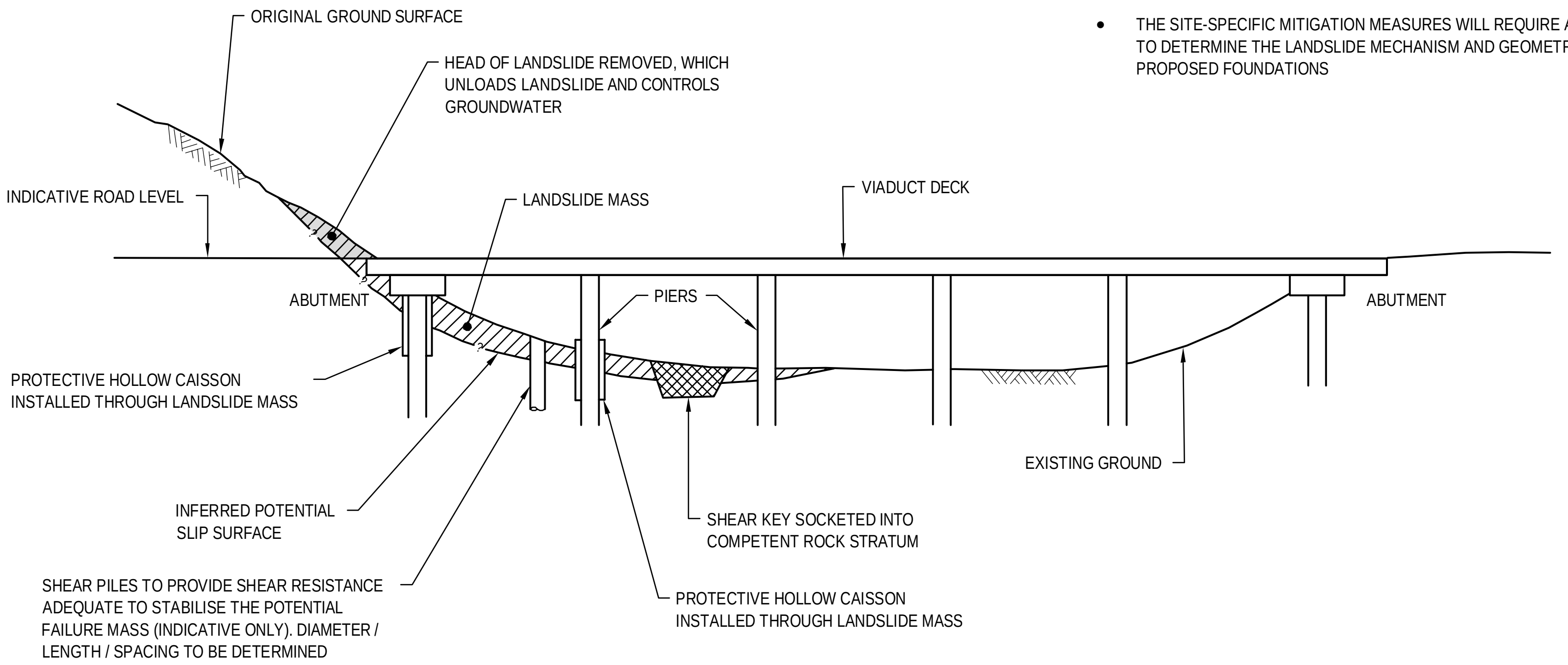
PŪHOI TO WARKWORTH - FOR RMA APPROVALS

DRAWN	DRAFTING CHECK	REVIEWED DISCIPLINE MANAGER	APPROVED ALLIANCE MANAGER
SNP	OJH	MRH	TI
DESIGNED OJH	DESIGN REVIEW DJW		

CONCEPTUAL LANDSLIDE TREATMENT OPTIONS SHEET 1 OF 2

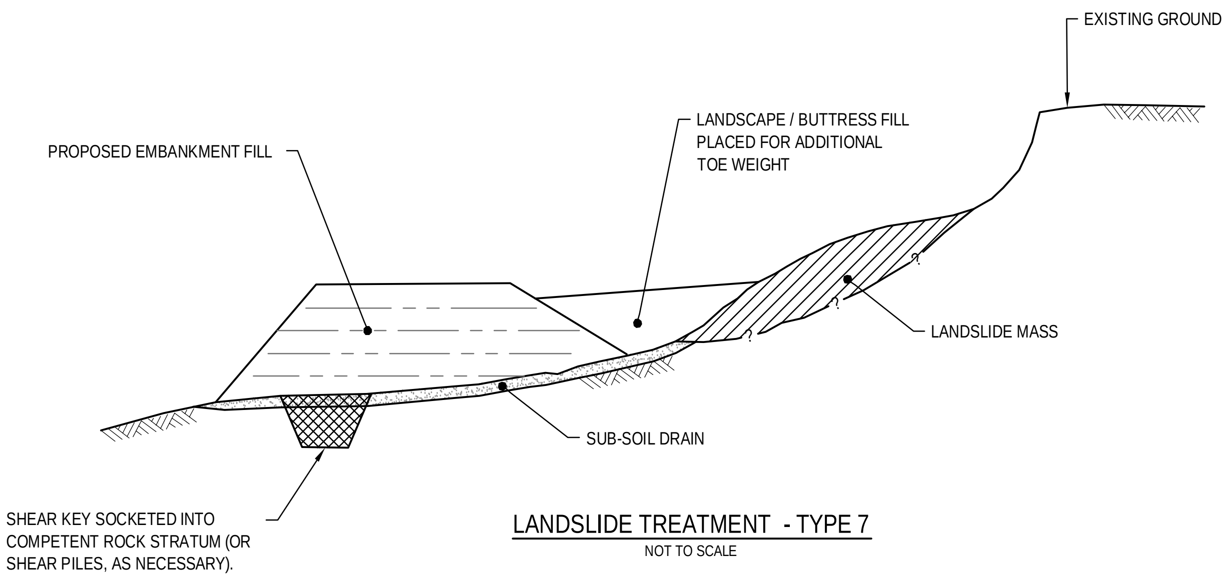
SCALE	CONTRACT No	DRAWING No	AMDT
NOT TO SCALE	PA3748	GT-301	0

- LANDSLIDE MASS REMOVED OR STABILISED WITH SHEAR KEY AND / OR SHEAR PILES
- VIADUCT FOUNDATION PILES TAKEN BELOW INFERRED LANDSLIDE SHEAR SURFACE(S)
- DRAWING IS INDICATIVE ONLY. DIAMETER / LENGTH / SPACING OF PILES TO BE DETERMINED
- THE SITE-SPECIFIC MITIGATION MEASURES WILL REQUIRE A DETAILED SITE INVESTIGATION TO DETERMINE THE LANDSLIDE MECHANISM AND GEOMETRY IN RELATION TO THE PROPOSED FOUNDATIONS



LANDSLIDE TREATMENT - TYPE 6

NOT TO SCALE



LANDSLIDE TREATMENT - TYPE 7

NOT TO SCALE

LEGEND

INTERPRETED LANDSLIDE MASS

0	30/08/13	DJW	MRH	TI	ISSUE FOR NOR / CONSENT
AMD	DATE	DESIGN REVIEW	REVD D. MGR	APPD A. MGR	PURPOSE OF ISSUE / AMENDMENT

FURTHER NORTH

DISCLAIMER

The information shown on this drawing is solely for the purposes of supporting RMA applications for statutory approvals. All information shown is subject to review for compliance with approved consents and the outcomes of final design.

ARA TŪHONO - PŪHOI TO WELLSFORD

PŪHOI TO WARKWORTH - FOR RMA APPROVALS

DRAWN	DRAFTING CHECK	REVIEWED DISCIPLINE MANAGER	APPROVED ALLIANCE MANAGER
SNP	OJH	MRH	TI
DESIGNED: OJH	DESIGN REVIEW: DJW		

CONCEPTUAL LANDSLIDE TREATMENT OPTIONS SHEET 2 OF 2

SCALE	CONTRACT No	DRAWING No	AMDT
NOT TO SCALE	PA3748	GT-302	0