Sunfield Developments Limited

PRELIMINARY GEOTECHNICAL ASSESSMENT REPORT

Sunfields Landholding, Ardmore

Project Reference: J01627
December 8, 2023

Document Control

Revision	Date	Comments
0	15.09.21	-
1	10.03.23	Additional property (279 Airfield Road) added to landholding and further investigation work completed.
2	08.12.23	Additional properties (119, 119A, 121A, 123, 131 & 143 Cosgrave Road) added to landholding and further assessments completed.

Revision	Issued For	Prepared By	Reviewed & Authorised By
2	Issued for Information	Kyle Meffan **Senior Engineering Geologist** CMEngNZ (PEngGeol)	Shane Lander **Principal Geotechnical Engineer** CMEngNZ, CPEng

This report represents the results of the geotechnical investigations and analyses carried out by LDE Limited for and in accordance with instructions received from Sunfield Developments Limited with regard to a specified development project application for the Sunfields Landholding, Ardmore.

If you have any queries or you require any further clarification on any aspects of this report, please do not hesitate to contact the engineers listed above.

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SYMBOLS:

S_u:	Undrained shear strength (kPa)	**LL**:	Liquid Limit (%)
N-value:	recorded from SPT	**PL**:	Plastic Limit (%)
q_c:	CPT cone resistance (MPa)	**PI**:	Plasticity Index (%)
m_v:	coefficient of volume compressibility (m^2/MN)	**LS:**	Linear Shrinkage (%)
y:	Bulk unit weight (kN/m^3)	**e_0:**	Initial Void Ratio
c':	Effective cohesion (kPa)	**e_f:**	Final Void Ratio
Ø':	Effective friction angle (degrees)	**$\rho_{d,i}$:**	Initial Dry Density (t/m^3)

1 EXECUTIVE SUMMARY

This summary outlines the principal geotechnical issues, design considerations and advice presented as part of our investigation and assessments for the Sunfield Development, Ardmore. Further details are presented in the relevant sections in the main body of the report.

Report Ref.	Geotechnical Consideration	Summary advice/recommendation
6.1 – 6.5	Ground Conditions	The site is underlain by extensive soft to firm organic PEAT soils and soft CLAY deposits generally in the western part of the site with variable depths of inorganic / organic stained crust up to 2.2m thick, although generally less than 1m thick. Isolated PEAT soils are also located along the eastern boundary adjacent to Ardmore Airport. The eastern part of the study area is generally defined by silty CLAY and clayey SILT deposits underlain by East Coast Bays Formation (ECBF) bedrock at depths of between 3.7m and 19.4m. For the purposes of site classification, the above soil groups (types) are referred to collectively as **Zone 1 (peats)** and **Zone 2 (inorganic clays)** respectively throughout this report – refer Figure 2.1.
6.6	Groundwater	Groundwater levels were recorded in piezometers on 30 April 2021, 30 July 2021, 27 October 2021, 17 January 2022, and 9 February 2023 at depths of between 0.20m and 7.17m below existing ground levels, although most locations recorded groundwater depths between 1.0m and 3m. This is considered to be generally representative of a year-round seasonal groundwater regime, with the February 2023 groundwater readings being undertaken during a historic high rainfall period in Auckland, however these show no significant deviations from the established trends.
6.7, 8.7	Percolation	Falling head percolation testing has determined that minimum percolation rates of between 0.0743 L/m2/min in Zone 2 soils and 0.01 L/m2/min in Zone 1 soils. It is paramount to minimise widespread consolidation settlements post-development that groundwater levels are maintained in Zone 1 soils through recharge of stormwater runoff via soakage pits and/or swales.
7.2	Slope Stability	Slope stability of the proposed 1(v) in 4(h) stormwater channel has been analysed and is considered satisfactory. Precedence has also been set by the recently constructed Takanini Stormwater Conveyance Channel, which is a larger system. Similarly, natural or proposed slopes elsewhere on the site will not exceed 1(v) in 4(h) and computer slope stability analysis is not usually warranted in this case.

Report Ref.	Geotechnical Consideration	Summary advice/recommendation
7.3.1, 8.1	Consolidation Settlements	Ground improvements to address consolidation settlements in Zone 1 soils will generally comprise ground improvements involving undercutting beneath building footprints and reinstatement with compacted hardfill or sand and/or preloading. Precedence has typically been set in the Takanini / Ardmore for these types of ground improvements in many significant subdivisions just to the west of Cosgrave Road.
7.3.2	Drawdown Settlements	Drawdown settlements are likely limited to the proposed stormwater channel which will incise below the surface of the surrounding (prevailing) topography. This should be addressed at Resource Consent stage.
7.4	Liquefaction	Most Zone 1 soils have been determined to be susceptible to liquefaction, especially where limited or no stiff crust is present. This is due to cyclic softening of the soft cohesive materials rather than dramatic 'sand boils' or lateral spreading. Ground improvements to address liquefaction can be addressed by the same ground improvements required for consolidation settlement (i.e. pre-loading and raft foundation design for buildings). Liquefaction induced total settlements should be considered in the subdivision design levels with regard to overland flow paths and floodplains, in order to maintain 'free board' following such an event. However, consolidation settlements from imposed earthworks and building loads is by far the greatest geotechnical engineering issue for consideration here.
8.1	Foundations	Foundations within Zone 1 areas for NZS3604 one to two storey light weight timber frame construction, heavier two storey, terraced (i.e. conjoined dwellings) or three storey dwellings will likely require some degree of ground improvement and stiffened raft foundations as outlined in Section 7.3, in conjunction with preloading. Buildings exceeding these loadings / storeys will likely be subject to piled foundations. Subject to further investigations, foundations in Zone 2 should be suitable for standard NZS 3604-type (i.e. lightweight) construction up to three storeys utilising strip and pad footings designed in accordance with AS 2870 and related documents. For commercial / industrial buildings within Zone 1, the foundation solution will be commensurate on end use and as such will require site specific investigations and foundation design. Examples of specific buildings and ground improvement / foundation solutions are presented in Section 8.1.1. For commercial / industrial within Zone 2 more conventional shallow foundations solutions are possible dependent on end-use, however,

Report Ref.	Geotechnical Consideration	Summary advice/recommendation
8.1 (cont.)	Foundations (cont.)	these types of buildings will generally require site specific investigation and foundation design. A summary table of preloading and/or localised ground improvement requirements and specific foundation design criteria is presented in Table 6.2 (Appendix 6.1).
8.2	Expansive Soils	Likely MBIE and/ or AS2870:2011 expansive site class classification for the finished subdivision is likely to fall within Classes M to H. Further assessments involving laboratory shrink-swell testing in accordance with MBIE guidelines should be completed at subdivision stage, provided undisturbed samples can be successfully obtained and tested in the peats (our understanding is that this is virtually impossible in type S1a geology).
8.3	Non-engineered Fills	An area of non-engineered fill has been identified in the south-eastern portion of the site. This material will need to be undercut and reinstated or ground improvement completed within proposed dwelling, infrastructure or roading areas subject to future master planning. There may be other areas of non-engineered fill and further comprehensive geotechnical site investigations during the subsequent Resource Consent stage(s) should minimise the risk of unforeseen areas of non-engineered fills in this regard.
8.4	Earthworks and Civil Works	Within Zone 1 areas, ground improvements will be required to mitigate settlements resulting from the proposed earthworks and building loads, which may include undercut and replacement, preloading and/or lag-periods following earthworks to allow settlements to attenuate. Earthworks in these areas require the use of track-rolled peat materials which are not covered by normal subdivisional compaction specifications. Within Zone 2, the cut materials should be suitable for re-use in other Zone 2 areas as certified clay fills which will need to be compacted to standard subdivisional compaction specifications. However, some degree of conditioning will likely be required to achieve suitable moisture contents for maximum compaction. Within the flatter Zone 2 areas (Stratum S2a), saturated and/or pumiceous soils can often be sensitive to disturbance (via pumping and weaving under earthwork plant). If/where this is encountered, undercutting and replacement of the affected soils will likely by necessary.

Report Ref.	Geotechnical Consideration	Summary advice/recommendation
8.5	Pipes and Buried Services in Peat Soils	Public service lines excavated in Zone 1 peat soils face a high risk of settlement of the pipes and redundancy should be built into the service design, such as oversizing pipeline internal diameters, careful consideration in selection of trench backfill materials, seepage cut off collars at regular intervals to prevent the pipe bedding media acting as a groundwater drawdown drain, increased bedding thicknesses, etc. Service lines will also need to be designed to withstand long-term corrosion and specialist advice will need to sought in this regard.
8.6	Roading	Within Zone 1 areas, road subgrades will require subgrade improvement due to the peats / weak crustal deposits. Precedence has been set in the Takanini / Ardmore area for 500mm to 900mm undercuts reinstated with ‘black sand’ laid upon geotextile cloth, whereupon targeted beam deflection values have then been achievable. Within Zone 2 areas, likely minimum CBR’s of between 2% and 4% should be available for pavement design purposes, and a more conventional approach to pavement construction should be available.

2 Scope of Report

LDE Limited (previously trading as Lander Geotechnical Consultants Limited) have been engaged by Sunfield Developments Limited to prepare a Preliminary Geotechnical Assessment Report (PGAR) in support of a specified development project (referred to herein as “the development proposal”).

We understand the application seeks to rezone approximately 244 hectares from Future Urban and Rural to Employment, Neighbourhood Centre, Park, and Mixed Housing Urban areas. The development proposal area consists of numbers 80, 85 & 92 Hamlin Road, 55, 55A, 101, 103, 119, 119A, 121A, 123, 131 & 143 Cosgrave Road, 508 Old Wairoa Road, and 279 Airfield Road. The study area is as outlined on the Maven Associates Limited drawings (Appendix 1).

Our work has entailed:

- A review of published geology maps, aerial photograph interpretation and observations of prevailing site geomorphology.
- A review of relevant geotechnical reports relating to the site as well as recent developments in the Takanini / Ardmore area (refer Section 3 below).
- A review of 15 No. Cone Penetrometer Tests (CPTs) undertaken by Initia within 279 Airfield Road in August 2022.
- A field investigation including:
  - The drilling of a series of hand auger boreholes (41 No.) to characterise near surface foundation and groundwater conditions to depths of up to 5m (bgl).
  - The drilling of a series of rotary cored machine boreholes (15 No.) to prove soil conditions beyond the reach of hand augers, to depths up to approximately 30m (bgl), and the installation of a piezometer within each machine borehole for the purposes of groundwater monitoring. Five groundwater monitoring rounds have been completed to date, with the first four rounds completed in April 2021, July 2021, October 2021, and January 2022 encompassing a full seasonal year of readings across the site, and the fifth round completed in February 2023 within 279 Airfield Road following the completion of further drilling at this property in December 2022.
  - The excavation of a series of trial pits (8 No.) to characterise near surface ground conditions and groundwater levels within the proximity of proposed stormwater channel or possible stormwater pond areas to depths of up to 3.2m (bgl).
  - The execution of 22 No. Cone Penetrometer Tests (CPTs) and 7 No. Dilatometer Tests (DMTs) to characterise the soils at depth.
  - The measurement of percolation (soakage) tests (2 No.) in accordance with TR 2013/040, Appendix A, Annexure C, Worksheet W1 – Falling Head Percolation Test
- Laboratory testing to characterise plasticity, particle size, pH (acidity) and compressibility characteristics of the various soil types.
- An assessment of slope stability risk within proposed permanent stormwater channel areas as per the recommendations of the Auckland Council Code of Practice (ACCoP), Chapter 2, 24 September 2013.

- An assessment of the settlement from the proposed earthworks and hypothetical foundation loadings to determine the magnitude of total and differential settlements.
- An aassessment of liquefaction risk in accordance with the latest guidance regarding liquefaction assessments, specifically MBIE "Planning and engineering guidance for potentially liquefaction-prone land: Resource Management Act and Building Act aspects"1, and MBIE/NZGS Module 3: "Identification, assessment and mitigation of liquefaction hazards"[2].
- The preparation of a preliminary geotechnical assessment report summarising our findings.

This report is intended to support a specified development project application and is <u>not</u> intended to be in a suitable format or of sufficient detail to advance a Resource Consent application(s). Further analysis for a Resource Consent application will need to be undertaken in due course, once earthworks plans are finalised and subdivision scheme plans have been progressed, and the data herein may be introduced into such report(s). It should be noted that potential flooding hazards are considered by others for this application (i.e. not LDE).

3 Related Reports

In preparing this report we have reviewed the following reports prepared by LDE Limited and Lander Geotechnical Consultants Limited (now trading as LDE Limited):

- *Winton Study Area in Ardmore – Desktop Geotechnical Appraisal*. Reference J01627, dated 7 December 2020.
- *Sunfields Development – Trial Preload Design and Settlement Monitoring*. Reference J01627, dated 17 November 2021.

We have also reviewed the following reports from GHD Consultants Limited relating to recent stormwater conveyance channel developments in the Takanini / Ardmore area, largely as a resource for soil parameter selection in local soft clays / peats to assist with our analyses:

- *Takanini Stormwater Conveyance Channel – Geotechnical Investigation Report;* Technical Report C. Reference 51/32174, dated December 2015.
- *Takanini Stormwater Conveyance Channel – Geotechnical and Ground Settlements Effects Report; Technical Report E.* Reference 51/32174, dated April 2016.

Based on our review of these reports, the following geotechnical constraints were identified which are also considered relevant to the development proposals at the Cosgrave Road development:

- Slope instability of the 1(v) in 4(h) stormwater channel.
- Soil liquefaction and associated surface settlement deformations due to cyclic softening of the soft cohesive materials. Lateral spreading is a lesser concern due to the flat nature of the site.

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[1] Earthquake Commission (EQC), Ministry of Business Innovation & Employment (MBIE) and Ministry for the Environment (MfE). "Planning and engineering guidance for potentially liquefaction-prone land: Resource Management Act and Building Act aspects" Rev. 0.1, Issue Date September 2017.

[2] New Zealand Geotechnical Society (NZGS) and Ministry of Business Innovation & Employment (MBIE) guidelines for Earthquake Geotechnical Practice in New Zealand. "Module 3: Identification, assessment and mitigation of liquefaction hazards" Rev. 1, Issue Date November 2021.

- Consolidation of the ground due to the proposed bulk fill and foreseeable end use building loads.
- Consolidation of the ground due to groundwater potential drawdown within areas of cut (i.e. specifically where stormwater conveyance channels are proposed).

4 Site Description, Geological Setting and geomorphology

4.1 Site Description

The site is bound by Cosgrave, Old Wairoa and Airfield Roads as well as similar rural residential properties. Hamlin Road runs through the central-northern portion of the study area. The majority of the site is in pasture. Several overland flow paths are shown to run through the site on Auckland Councils GIS database, however this will be confirmed by site specific survey by other members of the project team. Generally, overland flows are draining eastwards towards individual stormwater catchments or to local gullies / creeks in the south-eastern portions of the study area.

Site gradients across the study area are shown on Maven Associates Limited drawing C-200 (Appendix 1) and are generally less than 1(v) in 10(h), however, gradients up to around 1(v) in 4(h) are present on isolated slopes within the south-eastern portion of the study area. There were no obvious signs of active or relict instability across the study area.

A gas transmission line is present within the Cosgrave Road landholding and the location of this is indicated on the attached Auckland Council GIS service plan (refer Appendix 2).

Significant urban residential development is presently underway immediately adjacent to the north-west and west of the study area (i.e. residential subdivisions along Cosgrave and Grove Roads and the Addison Development). To the north-east is Ardmore Airport which contains several large buildings / hangers.

Our interpretation of available historic photographs on Auckland Council's online GIS database, Google Earth images and historic images from Retrolens.nz generally found only minor land modification on the study area over the period 1940 to 2017, however, an area of localised earthworks is identified on or prior to 1959 within the south-western portion of 508 Old Wairoa Road. The next available aerial photograph in 2001 shows the area to be grassed and in the same condition as of the time of preparing this report. This area is discussed in further detail in Section 6.2. Historic aerial photographs dated 1959 and 2001 are inset below.

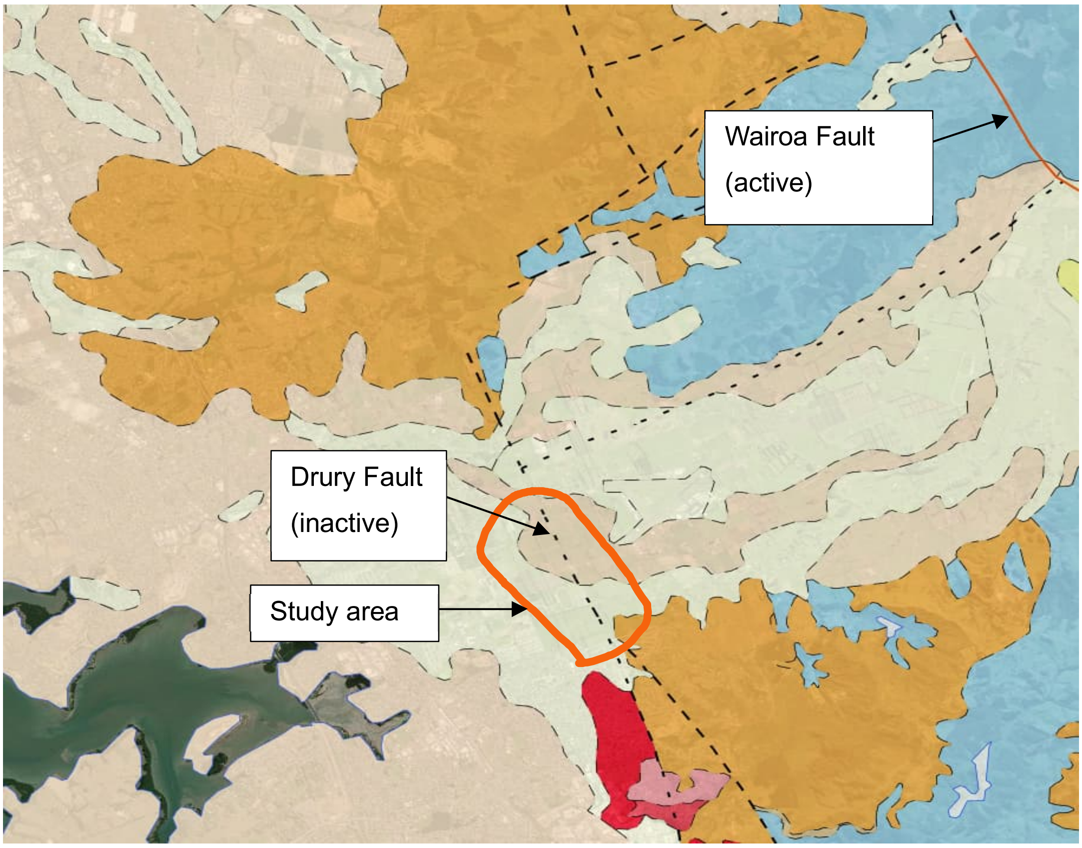
Inset A. Left: Photograph dated 1959, retrieved from Auckland Council GIS database. Area of earthworks circled in blue.
Right: Photograph dated 2001.

4.2 Geologic Setting

The GNS digital geological QMaps indicate the site is underlain by three geological units, from north to south as follows:

- Tauranga Group (indicated in light green shading, comprises undifferentiated Holocene river deposits) comprising sand, silt mud and clay with local gravel and peat beds.
- Puketoka Formation (indicated in tan shading, comprises late Pliocene to Middle Pleistocene pumiceous river deposits) comprising pumiceous mud, sand and gravel with muddy peat and lignite, rhyolite pumice including non-welded ignimbrite, tephra and alluvial deposits.
- East Coast Bays Formation (indicated in orange shading, comprises early Miocene turbidite deposits) comprising alternating sandstone and mudstone with variable volcanic content and interbedded volcanic grits.

Beyond the site to the south are deposits (Basalt and Ash / Tuff soils) of the South Auckland Volcanic Field (i.e. pink and red shadings on Inset B). The inactive Drury Fault runs through the site in a north-south fashion. Additionally, the Wairoa Fault (reportedly active, but last event unknown) is located approximately 10km to the east of the study area beneath the Hunua ranges. The position of these geological units and faults are summarised in Inset B below, and also in more detail in Figures 2.11 and 2.12 (Appendix 2).



Inset B: Published Geology (Institute of Geological and Nuclear Sciences. QMap geology. KMZ file. Available from https://services.arcgisonline.co.nz).

5 FIELDWORK PROGRAMME

Our fieldwork was undertaken in April 2021 and December 2022, and included the drilling of 41 No. hand auger boreholes (HA), 15 No. machine boreholes (MH), 8 No. trial pits (TP), 2 No. falling head percolation tests, 22 No. cone penetrometer tests (CPTs), and 7 No. dilatometer tests (DMT's). In addition, 15 CPTs undertaken by Initia within 279 Airfield Road have been supplied to us to supplement the tests undertaken under our supervision. Test positions are detailed on our site investigation plan (Figure 2.1; Appendix 2).

A piezometer standpipe was installed in each machine borehole and the site was re-visited approximately one week, three months, six months, and nine months following the completion of April 2022 drilling, as well as approximately two months following the completion of December 2022 drilling, to measure groundwater levels across the site over a full seasonal year. The standing groundwater levels are presented on Figure 2.2 (Appendix 2) and are also collated in Appendix 3.1.

Full records of all in-situ soil tests and groundwater monitoring, together with detailed descriptions and depths of strata encountered in the investigation locations are included in Appendices 3.2 to 3.7, and existing geotechnical data sourced from the New Zealand Geotechnical Database (NZGD) is presented in Appendix 3.8. Laboratory results selected from relevant MH's are included in Appendix 4.

A geotechnical model has been developed based on the available geotechnical information and is presented in Table 3.1 (Appendix 3). Additionally, eleven geotechnical cross sections through the site have been presented on Figures 2.3 to 2.10 (Appendix 2) detailing the thicknesses and depths of the materials across the site, together with measured groundwater levels and proposed earthworks levels (where known). General descriptions of the materials encountered across the study area are given in Section 6 below.

6 Summary of Ground Conditions

The site has been delineated into two specific assessment geotechnical zones based on the soil properties (natural soil types) defined as follows:

- Zone 1: includes all areas containing Undifferentiated Holocene deposits (Stratum S1a and S1b and underlying Stratum S2b to S2d) and generally comprises normally consolidated fibrous peats with variable thicknesses of inorganic or organic-stained crust material.

- Zone 2: includes all areas containing near-surface Puketoka Formation or East Coast Bays Formation deposits (Stratum S2a and S3a to S3c) and generally comprises inorganic, stiff to hard, over consolidated soils with Waitemata Group bedrock generally being found at depths of 12m or less.

6.1 Topsoil

Topsoil was encountered in most test locations and was between 100mm and 550mm thick, averaging 250mm.

6.2 Filling

No filling was detected at our borehole locations, however, during site works in July an area of uncertified filling comprising of intermixed topsoil, construction debris and rubbish materials was identified in the south-eastern portion of the study area during topsoil stripping operations for a proposed site office associated with this project. The full depth and extent of these materials are currently being determined by Focus Environmental at the time of preparing this report, however, the eastern extent of the materials identified by LDE Limited was located in approximately the same position as the earthworks operations observed in the 1959 aerial photograph presented in Section 4.1 of this report. The presence of similar rubbish pits should never be discounted elsewhere in farm environments, and further comprehensive geotechnical site investigations during subsequent Resource Consent phases should service to maximise the potential to discover these (if any).

6.3 Undifferentiated Holocene Alluvium (Zone 1 – 'Peat')

6.3.1 Crust Materials (Stratum S1a)

These materials comprise inorganic and organic stained silty CLAY and clayey SILT of firm to hard shear strength, although generally stiff. The inferred locations of these materials are indicated on Figure 2.1 which are generally located in the western part of the study area and the materials to depths of between 0.4m and 2.2m from existing ground levels.

6.3.2 Peat (Stratum S1b)

These materials comprise black and brown fibrous PEAT, with some variable beds of amorphous PEAT, CLAY, dilatant pumiceous SILT. These organic materials were very soft to very stiff, although generally firm. It should be noted that in some instances the measured undrained shear strength can be influenced by decomposing organic inclusions (i.e. tree roots or stumps) or skin friction on account of the boreholes collapsing due to the soft nature of the materials.

These materials were encountered beneath stratum S1a materials, however, Figure 2.1 shows the locations where materials were encountered without any surficial crust present, including isolated pockets along the eastern site boundary adjacent to Ardmore Airport. Where encountered, peat materials were typically recorded to depths of 18m to 20m from existing ground levels.

6.4 Puketoka Formation (both Zone 1 ‘Peat’ and Zone 2 ‘inorganic clays’)

6.4.1 Upper Over-consolidated Clays and Silts (Stratum S2a; Zone 2)

These materials comprise inorganic or organic stained silty CLAY and clayey SILT, with some variable beds of organic silty CLAY or organic clayey SILT. The materials were generally stiff to hard, and their locations on site are shown in Figure 2.1 to be in the central northern portions of the study area, generally extended to depths of between 6m to 12m below existing ground levels.

It should be noted that in HA06, HA38, HA39 and MH07, organic soils were present at depths between 0.0m and 2.0m. The presence of such localised organic deposits is not uncommon and has been identified in the nearby Park Estate and Auranga Residential Subdivisions in Drury which also contain similar Puketoka Formation soils.

6.4.2 Normally Consolidated Clays (Stratum S2b; Zone 1)

These materials comprise inorganic and organic CLAY with some variable beds of dilatant pumiceous SILT, and fibrous and amorphous PEATs. The materials are located beneath Stratum S2b materials typically to depths of between 18m and 27m, although in MH10 the materials extended beyond the reach of the 30m borehole depth. These soils are identified as being very soft to stiff, although generally soft to firm.

6.4.3 Loose Sands and Dilatant Silts (Stratum S2c; Zone 1)

These materials comprise very dense dilatant pumiceous SILTs and soft to firm clayey SAND and silty SAND deposits, and are generally located beneath stratum S2b materials (i.e. typically beyond 2m depth), commonly pinching out between the S2b and S2d materials, although in several instances similar materials were encountered above the S2b materials. These materials are 3m thick on average across all test locations, although an approximately 7m thick layer was encountered in MH14.

6.4.4 Lower Over-consolidated Clays and Silts (Stratum S2d; Zone 1)

These materials comprise inorganic and organic stained CLAY and silty CLAY with variable beds of fibrous PEAT and SAND. The materials are located beneath stratum S2b or S2c materials and are typically firm to stiff, with shear strengths generally increasing with depth. The materials extended beyond the 30m target depth of the relevant investigation locations.

6.5 East Coast Bays Formation (Zone 2 – ‘inorganic clays’)

6.5.1 Residual and Transitional Soils (Stratum S3a and S3b)

These materials comprise very stiff to hard inorganic silty CLAY and clayey SILT and are located in the south-eastern portion of the study area which is typically defined by having higher elevations and/or steeper slope gradients (up to 1(v) and 4(h) as mentioned in Section 4.1). Weathered residual soils were recorded to depths of between 3.7m and 4.3m overlying a distinct transitional layer (i.e. transition to bedrock), comprising dark grey, inorganic silty CLAY, clayey SILT and fine SAND deposits with some beds of highly to completely weathered interbedded SILTSTONE and SANDSTONE which become more common with depth.

6.5.2 Bedrock (Stratum S3c)

Bedrock materials were encountered beneath stratum S2a and S3b materials in the northern portions of the study area. The bedrock materials comprise extremely weak to moderately strong, slightly to completely weathered SILTSTONE and SANDSTONE.

6.6 Groundwater

Groundwater was encountered in most hand auger boreholes and trial pits across the site, with groundwater levels being encountered during drilling / excavation at depths of between 0.6m and 3.5m below existing ground level.

As discussed in Section 5, a standpipe piezometer was installed in each machine borehole and groundwater monitoring rounds were undertaken on 30 April 2021, 30 July 2021, 27 October 2021, 17 January 2022, and 9 February 2023 to determine the standing groundwater levels across the site once the groundwater levels had equilibrated following drilling, which is considered to be an accurate representation of the standing groundwater table.

Groundwater levels in the standpipes were measured at depths of between 0.20m and 7.17m below current ground level, however, most locations recorded groundwater depths within the upper 1.0m to 3m below ground level. This is considered to be generally representative of a year-round seasonal groundwater regime, with the February 2023 groundwater readings being undertaken during a historic high rainfall period in Auckland. Full records of groundwater are presented in Table 3.2 (Appendix 3.1).

6.7 Percolation Test Results

Two percolation tests (P01 and P02) were undertaken in the locations indicated on appended Figure 2.1. Tests were undertaken in accordance with TR 2013/040, Appendix A, Annexure C, Worksheet W1 – Falling Head Percolation Test (i.e. autumn conditions). Percolation rates are as indicated on the table below:

Table 1: Percolation Test Summary

Test	Minimum Percolation Rate	Test Depth	Soil Materials Summary	Pre-Soak Conditions
P01	0.0743 L/m^2/min	2.0m	Clayey SILT (low plasticity) / silty CLAY (high plasticity), very stiff, moist	7 Days
P02	0.01 L/m^2/min	2.0m	Fibrous / amorphous PEAT, soft to firm, moist to wet, low to medium plasticity	48 Hrs

6.8 Laboratory Test Results

Laboratory testing was undertaken to determine Atterberg Index properties, particles size distributions, one-dimensional consolidation properties and pH to characterise the subsoils at various locations and depths across the study area.

All results are IANZ (International Accreditation New Zealand) endorsed and these have been summarised in Table 4.1 (Appendix 4). Full laboratory results are included in Appendices 4.2 to 4.5 and are discussed in the following sections of this report.

7 PERCEIVED GEOTECHNICAL HAZARDS

7.1 General

It is apparent based on this preliminary work that with appropriate engineering there should be no insurmountable geotechnical hazards that would prevent future residential intensification. Precedence with residential development upon the alluvial 'Peat' geology setting has been set elsewhere in the Takanini / Ardmore region (i.e. the substantial residential subdivisions along Cosgrave and Grove Roads, Walters Road, Porchester Road and the Addison Development) and it is anticipated that a public reticulation network for stormwater and sewerage will be available for future large-scale subdivision development.

As discussed in Section 3 of this report, the following geotechnical hazards have been identified pertaining to urbanisation of the Sunfield landholding:

- Slope instability of the 1(v) in 4(h) stormwater channel.
- Soil liquefaction and lateral spreading.
- Consolidation of the ground due to the proposed bulk fill and building loads.
- Consolidation of the ground due to groundwater drawdown within areas of cut (i.e. the proposed stormwater channel).

The site-specific geotechnical assessment criteria and assumptions made for the hazard assessments and analyses in the following sections are described in Section 7.1.1 below.

7.1.1 Seismic Site Subsoil Class

The seismic site subsoil class for the study area has been determined in accordance with NZS 1170:5:2004. The assessed site classes for the study have been determined to be Class E (very soft soil sites) in Zone 1 and Class C (shallow soil sites) in Zone 2. For the hazard analyses presented in the following sections, Site Class C has been adopted site-wide as this provides a higher PGA and is therefore the most conservative approach. Further specific seismic testing (e.g. sCPT) during subsequent (more comprehensive investigations for Resource Consent) may help classify this further, particularly for the structural design of any infrastructure or buildings.

7.2 Slope Stability

The prevailing topography within Zone 2 soils currently has gradients no steeper than 1(v) in 4(h) with no obvious geomorphic signs of slope instability with the exception of localised over steepened gully flanks within the (S3 type) geology, where shallows seated slips and soil creep are generally observed as is expected.

The proposed earthworks scheme proposes to modify the existing site gradients to reduce slope gradients even further. Slope stability is not considered to be a primary geotechnical constraint within the Zone 2 areas of site because typical prevailing slopes (or proposed grades) do no exceed 1(v) in 4(h). Nevertheless, the proximity of buildings to sloping gully flanks that are left in place should be assessed as part of the future Resource Consent application(s) once the earthworks and subdivision proposals have progressed.

The soils within Zone 1 are considered to be potentially susceptible to slope stability at moderate to flat gradients due to their inherent weak nature, with the primary area of concern being the proposed 1(v) in 4(h) flanks forming the proposed stormwater conveyance which is to be incised entirely within 'crustal' materials or peat soils (i.e. S1 type). The Takanini / Ardmore area has recently seen the construction of the Takanini Stormwater Conveyance Channel which has also been formed at 1(v) in 4(h) gradient which is engineer designed, and to the best of our knowledge has not experienced any slope instability issues.

We have completed an analysis of the proposed 1(v) in 4(h) stormwater channel as shown on the Maven Associates Limited drawings (Appendix 1). The GHD reports[3,4] have been used to form the basis of our approach to slope stability assessments given that the current proposal involves a similar slope gradients and ground conditions to the Takanini Stormwater Conveyance Channel, although the channel in the landholding is nowhere as big as the GHD designed ones. A full description of our slope stability analyses together with detailed summary tables and full output results are presented in Appendix 5 of this report.

Based on our assessments slope stability assessments, assessed slip surfaces beneath the proposed permanent stormwater channel batters meets the minimum factor of safety criteria prescribed in the Auckland Council Code of Practice and are therefore satisfactory. Nevertheless, the proposed Landholding channel are subject to detailed design and it is recommended that further geotechnical assessments are completed once the final channel locations and geometries have been confirmed as part of a future Resource Consent application(s).

Specific slope stability assessments for lateral spread as outlined in MBIE Module 3[5] under earthquake loading are discussed in Section 7.4.2 below and in Appendix 5.

7.3 Compressible Soils

7.3.1 Consolidation Settlements

To assess the settlement caused by anticipated future building loads (one, two and three storey), a settlement analysis was completed using the CPT and DMT traces across the study area. A full description of how the building loads are derived, our settlement analysis together with detailed summary table and full output results are presented in Appendix 6 of this report.

Based on the results of the settlement assessment, total settlement beneath building loads are summarised for one, two and three-storey buildings, respectively, as follows:

Zone 1:

- Up to 183mm, 234mm and 286mm (using the DMT data).
- Up to 212mm, 317m and 423mm (using the CPT data)

Zone 2:

- Up to 9mm, 18mm and 27mm (using the DMT data).

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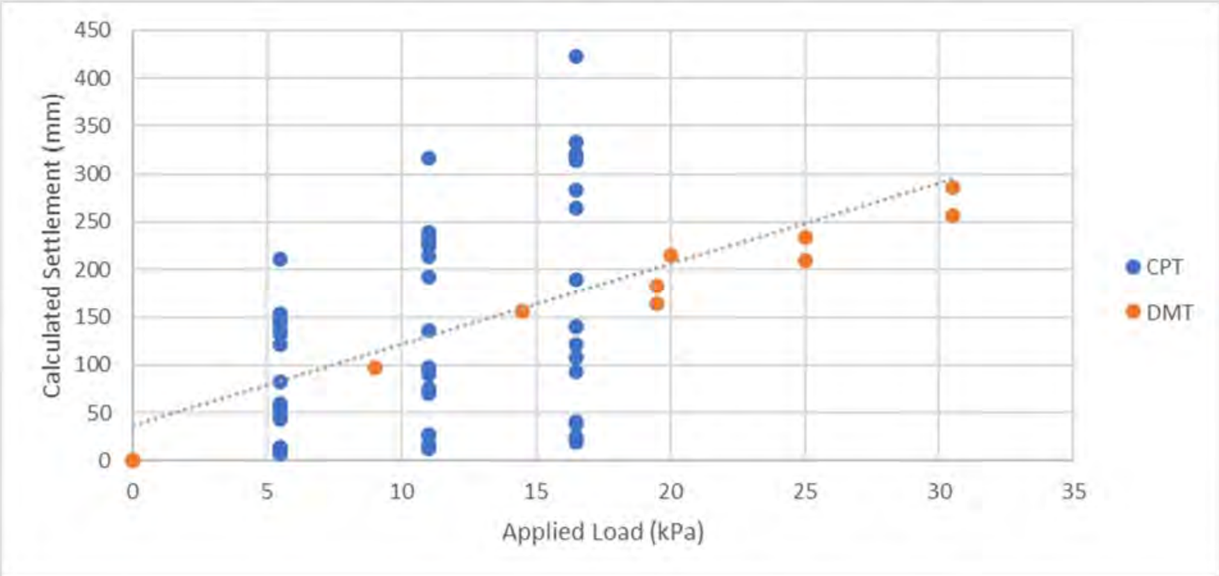
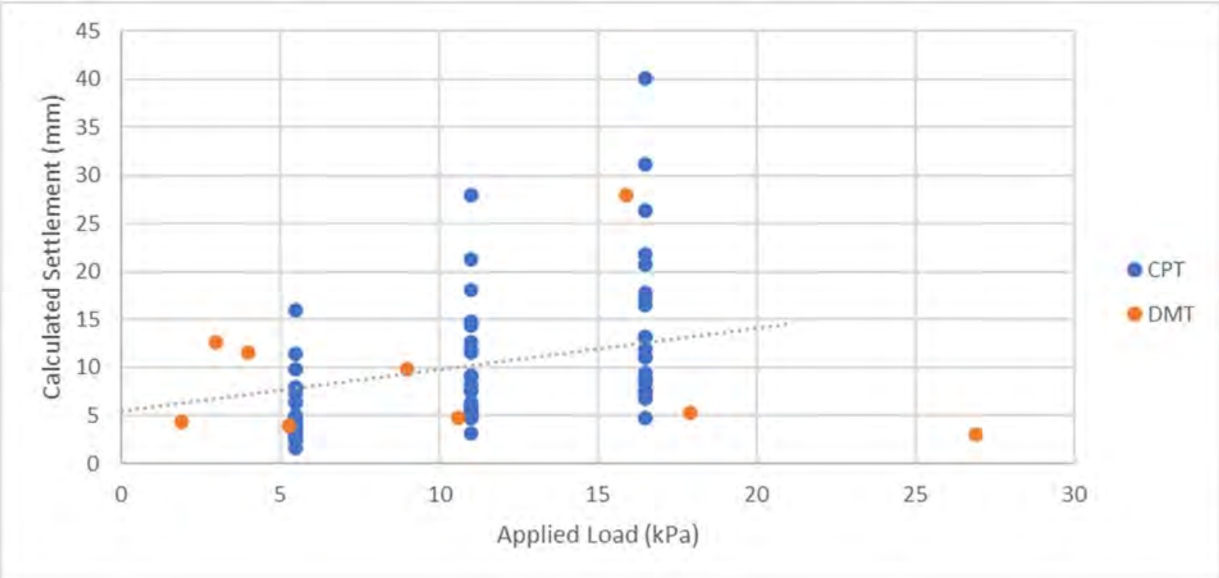
[3] Takanini Stormwater Conveyance Channel – Geotechnical Investigation Report; Technical Report C. Reference 51/32174, dated December 2015.
[4] Takanini Stormwater Conveyance Channel – Geotechnical and Ground Settlements Effects Report; Technical Report E. Reference 51/32174, dated April 2016.
[5] New Zealand Geotechnical Society (NZGS) and Ministry of Business Innovation & Employment (MBIE) guidelines for Earthquake Geotechnical Practice in New Zealand. “Module 3: Identification, assessment and mitigation of liquefaction hazards” Rev. 0, Issue Date May 2016.

- Up to 16mm, 28mm and 41mm (using the CPT data).

The insets below show a summary of the expected settlements calculated for both Zones. It should be noted that there is a reasonable disparity between CPT and DMT settlement estimations. DMT methods are widely regarded as a more accurate in-situ test for estimating settlements due to the direct measurement of the soil constraint modulus (M). Notwithstanding, trial preloading as alluded to later in this section will help assess actual response of the ground to surcharge application, as opposed to reliance on widely varying theoretical estimations.



Inset C: Applied Load vs Calculated Settlement for all Zone 1 assessments.



Inset D: Applied Load vs Calculated Settlement for all Zone 2 assessments.

Based on these preliminary analyses, the settlements are assessed to generally be acceptable for NZS3604-type buildings up to three-storeys constructed in Zone 2 areas, however, within Zone 1, all assessed tests were found to be in excess of this requirement as is expected in 'Peat'.

Precedence has been set to construction on similar ground conditions in nearby subdivisions and consolidation settlement is typically addressed by ground improvement (generally undercutting by around 500mm and replacing with compacted hardfill or sand beneath building platforms to act as a raft) and preloading to induce the settlements to be imposed by future building loads.

A preload design should be completed commensurate with a future Resource Consent application(s) and this will need to consider the final earthworks proposal, building typologies and uniformly distributed loads (UDLs) as well as the preferred preload material type, and trial preloads are recommended in this regard.

LDE Limited has been retained by Sunfield Developments Limited to provide geotechnical services for several preload trials to get a head start and quantify anticipated consolidation settlements and timeframes that can be expected under a preloading regime for the various building typologies and densities anticipated. At the time of preparation of this report, the preload design has been completed (refer Section 3), however, preload trials have not yet commenced.

The assessment for settlement beneath buildings greater than three storeys in Zone 2 has not been completed as part of this assessment, however, it is foreseeable that such construction would likely require piled foundations to support dwellings due to wind or seismic loading requirements. Such assessments should be addressed in further investigations if required.

7.3.2 Drawdown Settlements

Drawdown induced settlements occur where the soils experience dewatering to a groundwater level lower than that of the average seasonal variability. Groundwater drawdown is calculated as the difference between the proposed earthworks cut level and the season low in the groundwater levels (i.e. if the cut level extends below the seasonal low in the groundwater level then groundwater drawdown will occur). In Zone 1 soils, drawdown will create an increase in effective stress and induce settlement.

Our groundwater monitoring indicates seasonal fluctuations in the order of 1-2m between summer and winter. Over this zone of fluctuation the soils would tend to be pre-consolidated due to the effective stresses imposed. Over most areas of the site, cuts of around 1m or less are proposed and there is only minor groundwater drawdown risk, however, the primary concern for any such drawdown settlements is in the area of the proposed stormwater channel excavations. This is a matter for detailed design and should be assessed at Resource Consent stage.

Based on the existing groundwater data and earthworks proposals the following preliminary assessments of groundwater drawdown have been made for the proposed stormwater channel using the data presented in Figure 2.2 and Table 3.2:

Table 2: Preliminary Groundwater Drawdown Assessment

Location	Cut Depth	Lowest Measured Groundwater Level (m)	Groundwater Drawdown (m)
Stormwater Channel	1m to 2.5m	1.57m to 3.37m*	Up to 0.43m*

* We recommend further commentary be included during a future Resource Consent report(s) to address this risk, including the lateral extent affected by any drawdown. However, drawdown should only be assessed against the lowest recorded readings, which is generally the summer case.

7.4 Liquefaction and Lateral Spread Potential

7.4.1 Computer Liquefaction Analysis

Due to the variable nature of soils encountered across the study area (i.e. normally consolidated fibrous peat and clay deposits, pumiceous silty and sandy materials, over consolidated cohesive materials), a computer liquefaction assessment has been completed using the CPT data across the study area. A full description of our computer liquefaction analyses together with detailed summary tables and full output results are presented in Appendix 7.

No vertical settlements were calculated under SLS seismic conditions, however, under ULS seismic conditions, theoretical vertical settlements of up to 105mm (i.e. due to cyclic softening) were calculated, however, this does not take into account non-liquefiable crust thickness overlying the liquefiable layers, nor does it account for the Liquefaction Severity Number (LSN) for each analysis or the geological age of the soils. These criteria are outlined in Section 7.4.3 to 7.4.6 below and assessed vertical settlements following these assessments are presented in Section 7.4.7.

Lateral spreads are not considered to be a geotechnical concern as the site is generally flat and non-liquefiable crust layers across the site are generally thick enough to mitigate this as an issue (as there is no free face present for lateral spreading to develop). Additionally, lateral spread was not determined to be an issue in the proposed stormwater channel due to the Newmark Rigid-Block slope stability analysis (discussed in Section 7.2 and in Appendix 5).

In the following sections of this report we outline the relevant geotechnical criteria from relevant geotechnical publications for classifying soils as being prone to liquefaction and how they relate to the assessed results and the subsoils identified at the Cosgrave Road landholding.

7.4.2 Computer Lateral Spread Analysis

MBIE Module 3 indicates that lateral spread can develop where a factor of safety against liquefaction of less than 1.0 and a free face are present in combination (i.e. the proposed stormwater channel).

The Newmark Rigid-Block lateral spread assessment outlined in Appendix 5 indicate that no lateral spread occurs.

7.4.3 Geological Age

MBIE Module 3 advises aging of soils generally improves their resistance against liquefaction, and that liquefaction almost exclusively occurs in geologically young Holocene sediments, constructed fills and soils that have liquefied previously, and that in rare instances liquefaction of saturated sandy soils has been recorded in late Pleistocene soils (>11,000 years).

The soils within Zone 1 are of Holocene age and are therefore considered susceptible from a geological age perspective to the liquefaction calculated in our computer analyses.

The soils within Zone 2 are aged between Late Pliocene to Middle Pleistocene (11,000 years to 23 Ma). Soils of Late Pliocene age (Stratum S2a) comprise over consolidated cohesive materials and therefore considered to be less susceptible to liquefaction due to their age.

7.4.4 Soil Fabric

MBIE Module 3 states that ‘sand-like’ soils (sands, non-plastic silts and gravels) are most commonly susceptible to liquefaction and ‘clay-like’ soils (clays and clayey silts) are not susceptible to liquefaction, although the latter are soils of Holocene age may be susceptible to cyclic softening (as is the case at Cosgrave Road). The distinction between ‘clay-like’ and ‘sand-like’ soils are determined by the fine content of the soil, where ‘clay-like’ behaviour is defined as where greater than 30% of the dry mass can pass through a 0.075mm sieve (i.e. D_{30} <0.075mm (or 75μm)).

Additionally, MBIE Module 3 presents the following classification system for classifying liquefaction susceptibility in terms of the plasticity index of the soil for soils having a D_{30} <0.075mm:

Table 3. Liquefaction Susceptibility Criteria.

Plasticity Index Value	Susceptibility
PI <7	Susceptible to liquefaction (‘sand-like’ soils)
7 ≤ PI ≥ 12	Potentially susceptible to liquefaction; (possibly ‘sand-like’ soils)
PI ≥ 12	Not susceptible to liquefaction; (‘clay-like’ soils)

Preliminary laboratory testing has been completed for various soil types across the site to characterise their characteristics and behaviour. Plasticity index and particle size distribution testing indicate that materials described as ‘organic silty CLAY’ or ‘pumiceous silty CLAY’ comprise D_{30} of 1.4μm or less and have a PI of 40% or more (‘clay-like’), and materials described as ‘silty SAND’ or ‘pumiceous SILT’ comprise D_{30} of 19.7μm or less and have a were unable to be tested for PI (i.e. PI can be assumed to be 0 and therefore ‘sand-like’).

This indicates that the soils described as CLAY (generally in Zone 2 or lower Zone 1) are not susceptible to liquefaction, however, the Zone 1 soils described as SILT, pumiceous SILT and SAND are susceptible to liquefaction based on cohesion and plasticity index classification. However, these near surface non-cohesive deposits are thinly bedded, and peat is more prevalent.

Although not tested (on account of the difficulty of obtaining a sample suitable for testing), the fibrous PEATs which make up the majority of the near surface subsoils within Zone 1 generally have high moisture contents and a porous-fibrous structure and inherently can be classified as susceptible to cyclic softening (i.e. they can be treated as SILT or SAND in this sense).

7.4.5 Liquefaction Severity Number

MBIE Module 3 Table 5.1 indicates expected performance levels for liquefied deposits based on the Liquefaction Severity Number (LSN). The potential for ground surface damage as a result of the computer liquefaction settlements has therefore been evaluated using LSNs for each CPT assessed. As shown in Table 7.4 in Appendix 7, the CPT-based LSN values for ULS ground shaking are typically less than 10 with the remaining values in excess of 10 but still less than 15. This indicates insignificant to mild effects as a result of liquefaction as per MBIE Module 3 Table 5.1 (refer Inset E right).

Table 5.1: General performance levels for liquefied deposits

	EFFECTS FROM EXCESS PORE WATER PRESSURE AND LIQUEFACTION	CHARACTERISTICS OF LIQUEFACTION AND ITS CONSEQUENCES	CHARACTERISTIC F_L, LPI, LSN
L0	Insignificant	No significant excess pore water pressures (no liquefaction).	F_L > 1.4 LPI=0 LSN <10
L1	Mild	Limited excess pore water pressures; negligible deformation of the ground and small settlements.	F_L > 1.2 LPI = 0 LSN = 5 – 15
L2	Moderate	Liquefaction occurs in layers of limited thickness (small proportion of the deposit, say 10 percent or less) and lateral extent; ground deformation results in relatively small differential settlements.	F_L = 1.0 LPI < 5 LSN 10 – 25
L3	High	Liquefaction occurs in significant portion of the deposit (say 30 percent to 50 percent) resulting in transient lateral displacements, moderate-to-large differential movements, and settlement of the ground in the order of 100 mm to 200 mm.	F_L < 1.0 LPI = 5 – 15 LSN = 15 – 35
L4	Severe	Complete liquefaction develops in most of the deposit resulting in large lateral displacements of the ground, excessive differential settlements and total settlement of over 200 mm.	F_L << 1.0 LPI > 15 LSN > 30
L5	Very severe	Liquefaction resulting in lateral spreading (flow), large permanent lateral ground displacements and/or significant ground distortion (lateral strains/stretch, vertical offsets and angular distortion).	

Inset E: General performance levels for liquefied deposits.

The average LSN for the Zone 1 soils for the ULS case is approximately 2.4, while the average LSN for the Zone 2 soils is approximately 9.2. This indicates insignificant to mild liquefaction effects generally prevail under ULS shaking across both of these zones, resulting in limited excess pore water pressures, negligible deformation of the ground and small settlements only.

7.4.6 Surface Manifestation Criteria

MBIE Module 3 provides guidance around consideration of crust thickness. A non-liquefiable crust thickness of 3m is generally deemed thick enough to suppress surface manifestation of deep liquefaction occurrence for earthquakes with a PGA of 0.2g or less.

Research completed by Bowen & Jacka (2013)[6] has compared this theory to the damage recorded during the 2010 and 2011 Canterbury earthquake sequence which also found that where the crust thickness of 3m or more is present (for a PGA of 0.2g), liquefaction was considered unlikely to occur as the crust thickness was considered too thick for the underlying liquefied soils to 'break through', for example in the case of sand boils. The research also suggests

[6] Bowen, H. & Jacka, M. (2013) "Liquefaction induced ground damage in the Canterbury earthquakes: predictions vs reality" Proc. 19th NZGS Geotechnical Symposium.

that the thickness of the underlying liquefied layer is a less important factor except in instances where a liquefied layer of between 0.5m and 2.0m were present within the upper 3m. The results of our computer liquefaction analysis have considered the thickness of non-liquefiable crust layers, and these demonstrate that the non-liquefiable crust thickness was between 1.3m and 6.3m under ULS seismic conditions, with the resulting ULS settlements up to 105mm (refer Table 7.4). A significant number of CPTs in Zone 1 (11 out of 19) have non-liquefiable crusts less than 3m thick, while out of the Zone 2 CPTs, only 7 out of 20 have non-liquefiable crusts less than 3m thick. Based on this, the Zone 1 soils could have more surface manifestation of liquefaction during a ULS earthquake, while the Zone 2 soils are generally not expected to show surface manifestation based on crust thickness criteria.

Based on our assessment of geological ages, soil cohesiveness, and surface manifestation criteria, the Zone 1 soils are possibly susceptible to liquefaction only under ULS shaking with calculated settlements of up to 105mm, while the Zone 2 soils are considered to be less susceptible to liquefaction.

7.4.7 Development on Liquefaction-Prone Soils (Zone 1)

The results of this liquefaction analysis (based on a post-construction earthworks scenario) indicate that soils which have been identified as susceptible to liquefaction / cyclic softening (i.e. Zone 1 soils with no sufficient non-liquefiable crust) and assessed to possibly undergo liquefaction-induced settlement under ULS conditions could be between approximately 5mm and 130mm. These figures are only preliminary and future assessments should be completed as part of a Resource Consent application(s).

Due to the potential for liquefaction-induced settlements, the subdivision will need to be designed with this in mind, with a regard to overland flow path, floodplain levels and maintaining free-board for building platforms, etc.

Additionally, MBIE Module 5[7] outlines several methods of ground improvement that can be used in soils which are assessed to be susceptible to liquefaction. Of the methods of ground improvement, the following methods are considered to be the most applicable to the proposed development based on precedence set in the area (see section 8.1.1 also) at nearby subdivisions and as these methods will also address the consolidation settlements as discussed in Section 7.3.1:

- <u>Replacement</u>: involves the undercutting of the upper liquefaction prone soils and reinstating with a non-liquefiable material. This is commonly a compacted GAP65 hardfill material which acts as an additional raft beneath the future building and also improves the available bearing capacity available for future buildings. In peat soils this may be problematic for construction due to the high groundwater table, and for consolidation settlements due net increases in stress (e.g. from hardfill reinstatement).

- <u>Densification</u>: involves the rearrangement of soil particles into a tighter / denser configuration. This can be achieved in part via preloading, which is also required to remove building induced settlement as discussed in Section 7.3.1.

[7] New Zealand Geotechnical Society (NZGS) and Ministry of Business Innovation & Employment (MBIE) guidelines for Earthquake Geotechnical Practice in New Zealand. “Module 5: Ground improvement of soils prone to liquefaction” Issue Date June 2017.

7.5 Proximity to Faults

Based on a review of the GNS digital geological QMaps, it is apparent that there are several identified faults in proximity to the study area. The Drury Fault runs through the study area and is classified by GNS as inactive. The likely return period of the Drury Fault is considered to be in the order of several thousand years or more8. The nearest defined active fault is the Wairoa North Fault which is located approximately 10km to the east of the study area (refer Fig 2.12).

Due to the distance of the site to the nearest active fault being 10km and the existence of other Urban and Future Urban developments in similar or closer proximity to the Drury Fault (i.e. residential subdivisions along Cosgrave and Grove Roads and the Addison Development), we consider that the fault should not be considered a high impact geotechnical issue to this development.

7.6 Expansive Soils

A phenomenon common to the plastic soils found throughout this region is their expansive nature and tendency to shrink and swell, particularly with seasonal fluctuations of near surface water contents. Geotechnical engineering solutions to expansive soils are discussed in Section 8.2 below.

7.7 Flood

The Auckland Council Geomaps database indicates that flood plains within the study area are generally confined to the identified overland flow path areas and we understand these will be assessed by other specialist reports accompanying the application.

7.8 Regional Hazards

7.8.1 Earthquake

As stated above, the Cosgrave Road landholding is located 10km from the nearest active fault (the Wairoa North Fault). Notwithstanding, all future foundations for structures should be seismically designed in accordance with the relevant New Zealand Standards and guidelines.

7.8.2 Tsunami

The landholding is located approximately 2.5km from the nearest Tsunami shore exclusion zone and evacuation zones as per Auckland Councils Geomaps database, which are adjacent to the Pahurehure Inlet. Tsunami should be dismissed as a likely hazard.

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[8] Williams et al. 2006. "Active Faulting in the Auckland Region, Earthquake and Urban Development," New Zealand Geotechnical Society, IPENZ, Proceedings or Technical Groups Vol.31.

7.8.3 Volcanic

The landholding is located relatively close to the South Auckland Volcanic Field, which is considered to be extinct, and is around 9km from the nearest Auckland Volcanic Field Volcanoes (Matakarua, Manurewa and Ash Hill mountains in Wiri). Leonard and Roberts (2017)[9] highlights the difficulty in forecasting future eruption timelines and locality in the Auckland Volcanic Field and argues that given the population and extent of economic and urban development in Auckland, avoidance of this hazard is not feasible, but rather risk should be mitigated through contingency and emergency planning at a regional level.

8 GEOTECHNICAL ENGINEERING CONSIDERATIONS

8.1 Foundations for Buildings

8.1.1 Zone 1

Based on the results of our field investigation and subsequent settlement analyses, soils in this area of the site comprise generally fibrous peats (Stratum S1b) with varying degrees of stiffer crustal thicknesses (Stratum S1a) generally through the central and western portions of the study area. Crust thicknesses of up to 2.2m are present, although are generally less than 1m thick. However, there is the potential for 'crust thicknesses' to increase by up to 1m in some areas due to the proposed bulk filling works.

Within S1a areas, one and two storey light weight standalone residential dwellings will generally require undercutting beneath the building footprints by 500mm and replacement with compacted hardfill or approved sand, in conjunction with a geotextile cloth to separate the backfill from underlying soft subgrades. Localised preloading may be required; however, this should be assessed during future site-specific investigations.

Within S1b areas, one and two storey light weight standalone dwellings will require ground improvement as required for S1a areas plus a wider preload. Preload details should be confirmed commensurate with specific building proposals at Resource Consent stage.

For both S1a and S1b areas, heavier two storey, or terraced (i.e. conjoined residential dwellings), or three storey on natural ground will require the undercutting plus a higher degree of preloading. Preloads can be in place for anywhere between 6 and 18 months based on precedence. Preload trials are recommended to observe actual response of the soils to surcharges loadings (LDE Limited have been retained to provide geotechnical inputs into such trials, with preload design completed at the time of preparation of this report – refer Section 3).

Alternatively such buildings could be piled or some other deep ground improvement option implemented to mitigate settlement and bearing capacity concerns.

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[9] Leonard, G. A. & Roberts, R. C. Volcanic Hazard from the Auckland Volcanic Field. Proceedings 20th NZGS Geotechnical Symposium. 2017.

For commercial / industrial buildings within Zone 1, the foundation solution will be commensurate on end use and as such will require site specific investigations and foundation design. There is precedence of large buildings having commercial / industrial end-use in Takanini peats, and solutions such as piling, soft pile rafts, ground improvement and preloading etc. have been utilised.

All building types constructed on peat soils will require stiffened pod-raft type foundation solutions to spread building loads evenly in order to minimise the potential for differential settlements.

Other floor slab systems may be appropriate provided that they are the subject of specific site investigation and foundation design by an appropriately experienced Chartered Professional Engineer. Roofing systems should preferably be light weight and the exterior cladding should preferably be flexible or at least contain adequate control joints as specified by the Architect/ Engineer.

Private services entry points into houses with require flexible connections and driveways will need a transition slab into the floor slab to minimise cracking / distress between these elements.

A summary table of preloading and/or localised ground improvement requirements and specific foundation design criteria is presented in **Appendix 6.1.** A summary of specific buildings and ground improvement / foundations solutions adapted for commercial / industrial buildings is presented in Table 4 below.

Table 4. Commercial / Industrial Ground Improvement and Foundation Solution Case Studies (for Zone 1 areas).

Location / Building	Building Working Load	Ground Improvement	Foundation Solution
Sikh Temple, 70 Takanini School Road	20kPa	N/A	8m deep piled foundations (to relatively shallow ECBF bedrock)
Gymnasium and Multi-Sports Centre, Bruce Pulman Park, Walters Road	Unconfirmed, typically 'lightweight'	Stage 1 (single storey) - 1400mm high preloading, average settlement of 142mm recorded Stage 2 (two-storey) - 1700mm high preloading, average settlement of 500mm recorded	foundation pads and floor slab thickenings
Mitre 10 Centre, 238 Great South Road	10kPa	500mm thick hardfill raft	Timber driven piles (for column loads) Strip footings (for external tilt slab walls)

8.1.2 Zone 2

Where inorganic natural ground is present, bearing capacity is expected to be in accordance with the limitations imposed by NZS 3604 where 300kPa geotechnical ultimate bearing capacity should be adopted. However, as is evident from our borehole findings, some areas contain pockets of weaker ground and/or lenses of organics.

Softer ground or lenses of organics can pose constraints to NZS 3604 building foundations and residential end use, necessitating remediation during earthworks construction (e.g. undercutting and reinstatement with stronger soils), and/ or specifically designed foundation solutions (i.e. 'raft' foundations). LDE's experience in the delivery of hundreds of lots in the nearby area on Puketoka Formation soils (i.e. the Auranga Residential Subdivision in Drury) indicates that typically only a small number of lots are affected by soft ground or organic soils, but in due course more intensive physical site investigation associated with a subdivision scheme will substantiate this risk.

For commercial / industrial within Zone 2 more conventional shallow foundations solutions are possible dependent on end-use, however, these types of buildings will generally require site specific investigation and foundation design.

8.2 Expansive Soils

A phenomenon common to the plastic soils found throughout this region is their expansive nature and tendency to shrink and swell, particularly with seasonal fluctuations of near surface water contents. Expansive soils are outside the provisions of NZS 3604 (according to its definition of "good ground") and therefore foundations on such soils require specific design to establish appropriate embedment depths and/ or concrete reinforcement configurations.

Based on the preliminary laboratory testing undertaken and our knowledge of the soils encountered within this area of Auckland, the assessed expansive site class for this site is as follows when assessed in accordance with AS2870:2011 guidelines is as follows:

- Class M (moderate)* to Class H2 (high)*
- Characteristic ground movement of 40mm and 75mm, respectively*

**Note: This AS2870:2011 assessment is based on the scaling factor of the site being adjusted to a 1/500yr event to meet the recommendations of MBIE.*

It is foreseeable that foundation design in Zone 2 may be carried out in accordance with AS2870:2011 provided they are designed to the recommendations above on expansive site class and characteristic ground movement or alternatively an engineer approved design solution may be adopted.

Within Zone 1 areas, consolidation settlement of the underlying peat soils and the need to charge groundwater will govern here, not expansivity.

This will be addressed in greater detail as part of a Resource Consent report and will need to consider proposed earthworks.

8.3 Non-engineered Fills

As described in Section 6.2, some pre-existing filling is present within the landholding and is likely associated with an old rubbish pit.

Where deemed economic to do so, pre-existing filling will need to be undercut and reinstated with engineer certified filling to mitigate the risk of differential settlement and bearing capacity issues associated with non-engineered filling.

If there are any fill depths which are considered too deep for undercutting and reinstatement to be a viable option, specific foundation design will be required to mitigate the aforementioned risks, with a view to pile foundation solutions or ground improvement. This is a matter to be re-addressed as part of a Resource Consent geotechnical report.

8.4 Earthworks and Civil Works

8.4.1 Zone 1

The risk of ground settlement in this area requires that careful mitigation measures be implemented to ensure that any settlements that do occur are within acceptable limits. Surficial soils within Zone 1 are relatively sensitive to disturbance and any earthworks and construction operations should be undertaken with care.

Based on the results of our settlement analyses, a large portion of Zone 1 could be subject to significant consolidation settlements which will be in excess of Building Code limits for differential settlements. It is our view that development in these areas should be subject to ground improvements comprising of the undercutting and replacement of weaker soils immediately beneath the foundations or the preloading of the building platforms following post-construction earthworks. Additionally, in some areas, a lag-period could be implemented where construction is able to commence without additional ground improvement following, say 1-year, to allow fills to settle under their own self-weight. Such assessments should be made at Resource Consent stage when further detail is available regarding the proposed development schemes.

Control of post-construction settlement is usually reduced through appropriate engineering design, such as preloading if required, identification and removal of buried tree stumps/ logs from beneath building platforms and service line corridors, and settlement monitoring of fills. Stump detection involves probing to 2m depth in a grid fashion (say 3m centres) using a special attachment on a digger, and excavation of any obstructions encountered and replacement with peat or black sand.

With regard to bulk filling, normal subdivisional compaction specifications do not apply to these organic materials if they are used as fill. The materials are best bladed out to a uniform thickness and screened using a root rake to remove as much large matter as possible. The materials are then track rolled and allowed to drain and harden over time. Light re-compaction once moisture contents have reduced during favourable site conditions is prudent. This methodology has been widely used in other nearby developments on peat soils over the past 10 years or so (e.g. Addison).

8.4.2 Zone 2

Based on our previous experience in the area we expect that the natural soils on site should generally be suitable as borrow materials. Moisture contents in laboratory samples tested were generally higher than the plastic limits, indicating that they will likely require conditioning prior to placement as engineer certified filling. However, these samples were collected in winter and more favourable conditions could possibly be observed during summer conditions.

Puketoka Formation soils, particularly pumiceous soils (which are common in Puketoka Formation), can be sensitive to disturbance during earthworks and trafficking with pumping and weaving occurring under heavy machinery trafficking (i.e. the subgrade may lose strength and become difficult for primary earthworks machinery to traverse). If sensitive and/ or pumiceous soils are uncovered near to proposed levels on site, appropriate earthworks methodologies and programming should be implemented to avoid disturbing these materials. This can include keeping machinery trafficking to designated haul roads and maintaining levels at 200mm-300mm above final level until topsoil or basecourse can be placed. Where these soils are disturbed, undercutting and reinstatement of the disturbed soil mass with engineered filling will likely be necessary.

Sensitivity to disturbance can also cause the degradation of roading subgrades once exposed. This can be avoided by careful construction sequencing or mitigated by subgrade improvement such as undercutting and replacement or lime stabilisation etc.

It is likely such areas will be determined in greater detail as part of further investigations commensurate with separate Resource Consent application(s).

8.5 Pipes and Buried Services

The laying of deep pipelines in ground with a high groundwater table can be extremely difficult and is best undertaken by a Constructor with a proven track record in this regard (i.e. laying pipes in peat).

If flat grades are proposed then the risk of settlement dipping the lines increases, and redundancy should be incorporated into the design, such as oversizing pipeline internal diameters, careful consideration in selection of trench backfill materials, seepage cut off collars at regular intervals to prevent the pipe bedding media acting as a groundwater drawdown drain, etc.

Increased bedding thickness and undercut to provide a uniform support to the pipelines will also be necessary. It is important to note that despite design and construction best efforts, differential settlement on flat service lines always poses a risk and cannot be completely mitigated in this terrain. It will be important to ensure settlement in bulk fill areas has attenuated to acceptable level prior to the laying of minimal grade service lines and roading kerbs, etc. This is an important construction sequencing issue.

Deep trench fills (e.g. greater than 3m) if hard filled may induce settlements that dip lines, so lightweight fills (e.g. PolyRock) or Puni sand with 3% cement (i.e. to immobilise it) may be warranted.

It is also important that services pipes are designed to withstand long-term corrosion. We anticipate that specialist advice will need to be sought for assessments in accordance with AS4058:2007 Appendix E, Table E1 (or current standard) as to concrete pipe resistance to the corrosive nature of the soils (refer Appendix 8 for site specific pH results). Further chemical testing and analyses of the organic soils/groundwater may be required for this (e.g. pH, total alkalinity (mg/L), Baumann-Gully acidity (mL/kg), chloride and sulphate (mg/kg)).

8.6 Roading

Roading subgrades within Zone 1 peaty soils will be extremely soft but precedence has been set in the area. Subgrade improvement undercuts typically comprise of ranges from 500mm to 700mm. The undercuts are typically reinstated with black sand (e.g. sourced from Woodhill or Waiuku), with a geotextile cloth placed to separate the sand from the underlying subgrade. The roading materials themselves may involve settlement of the underlying subgrade and requirement for additional depths of roading aggregate may be experienced as a 'top up' to achieve design levels. Our experience with Benkelman Beam deflection testing in the local area (e.g. on 700mm thick sand improvements) indicates deflections of close to 1mm are normally achievable, which seems to improve in time as the pavement 'sets up'. The deflection target criteria are normally 1mm for main through roads and 1.5mm for lesser roads.

Within Zone 2 soils, likely minimum CBRs of between 2% and 4% will likely be available for pavement design purposes.

8.7 Stormwater Management

LDE Limited (previously Lander Geotechnical Consultants Limited) have performed falling head stormwater percolation testing in two locations shown on our site plan (Figure 2.1) in accordance with the method described in the Auckland Council stormwater design manual TR2013-040.

Minimum percolation rates ranged from 0.01 L/m^2/min (within fibrous PEAT soils) to 0.0743 L/m^2/min. Based on these results and comparison to Table 4 of TR2013-040 we consider that in-situ percolation at Cosgrave Road will be likely be poor within identified CLAY deposits (i.e. Stratum S2a and S3a).

Within Zone 1 it is vital that existing groundwater levels within the Zone 1 peaty soils are maintained through recharge of stormwater runoff via soakage pits and/ or swales to minimise the potential for widespread drawdown and associated consolidation settlements. Within Zone 2 stormwater should be disposed of via specifically designed soakage pits or alternatively into the stormwater reticulation network.

9 Conclusions

Overall, the landholding is considered suitable for urban intensification as has been done on other topographically large land holdings to the west in similar geologies, and we therefore support the development proposal.

Further site investigation, and/ or design analyses will be required as part of the Resource Consent process in due course, commensurate with earthworks plans.

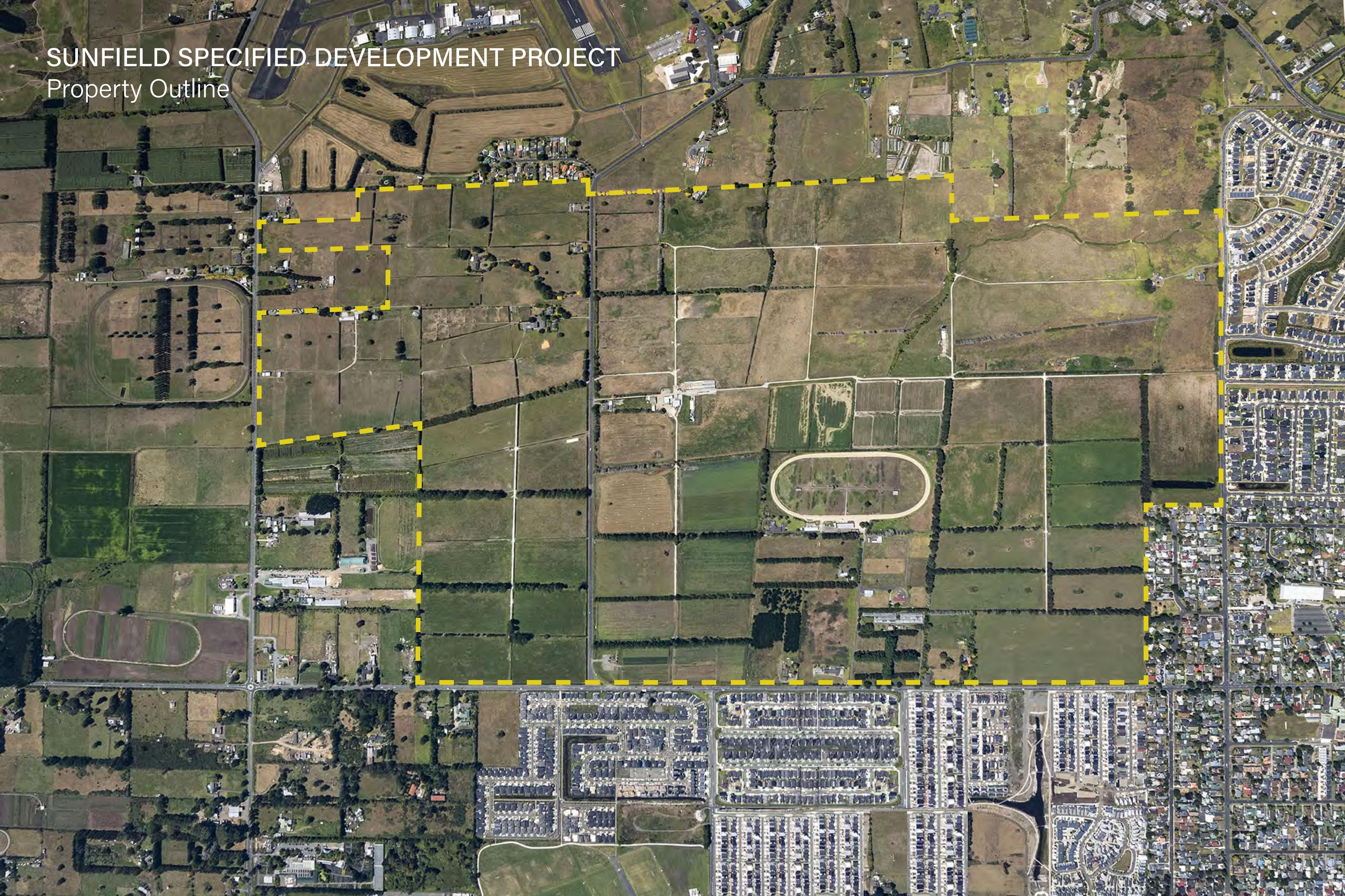
10 LIMITATIONS

This report has been prepared solely for the use of our client, Sunfield Developments Limited, its professional advisers in relation to the specific development proposal brief described herein. No liability is accepted in respect of its use for any other purpose or by any other person or entity. All future owners of this property should seek professional geotechnical advice to satisfy themselves as to its ongoing suitability for their intended use.

The opinions, recommendations and comments given in this report result from the application of normal methods of site investigation. As factual evidence has been obtained solely from boreholes which by their nature only provide information about a relatively small volume of subsoils, there may be special conditions pertaining to this site which have not been disclosed by the investigation and which have not been considered in the report.

APPENDIX 1

CLIENT SUPPLIED DRAWINGS


SUNFIELD SPECIFIED DEVELOPMENT PROJECT
Property Outline

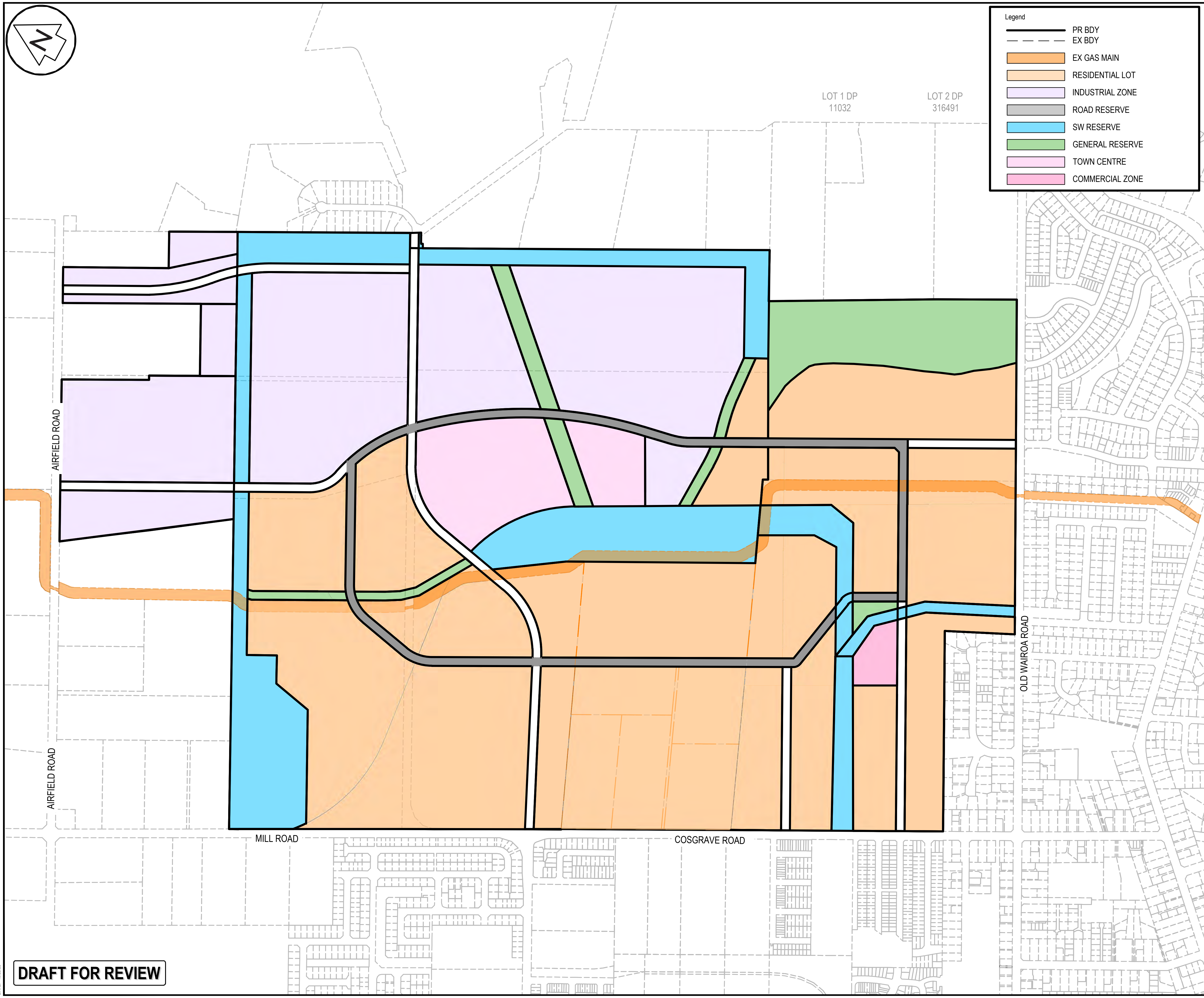

SUNFIELD SPECIFIED DEVELOPMENT PROJECT
Property Outline

SUNFIELD SPECIFIED DEVELOPMENT PROJECT

Property Outline


SUNFIELD SPECIFIED DEVELOPMENT PROJECT
Property Outline


SUNFIELD SPECIFIED DEVELOPMENT PROJECT
Property Outline



A	INFORMATION	CE	10/2023
Rev	Description	By	Date

	By	Date
Survey	-	-
Design	CE	02/2023
Drawn	ML	02/2023
Checked	JP	02/2023

MAVEN
Maven Associates
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5 Owens Road, Epsom
Auckland 1023

Project
PRELIMINARY SUPER-LOT CONCEPT PLAN FOR WINTON PROPERTY

Title
PROPOSED CONCEPT PLAN MILL ROAD OPTION 2

Project no.	215001		
Scale	1:8000 @ A3		
Cad file	C100 CONCEPT PLAN OPT 2.DWG		
Drawing no.	C100	Rev	A

Sunfield Masterplanned Community

Concept Masterplan - 29.11.2023

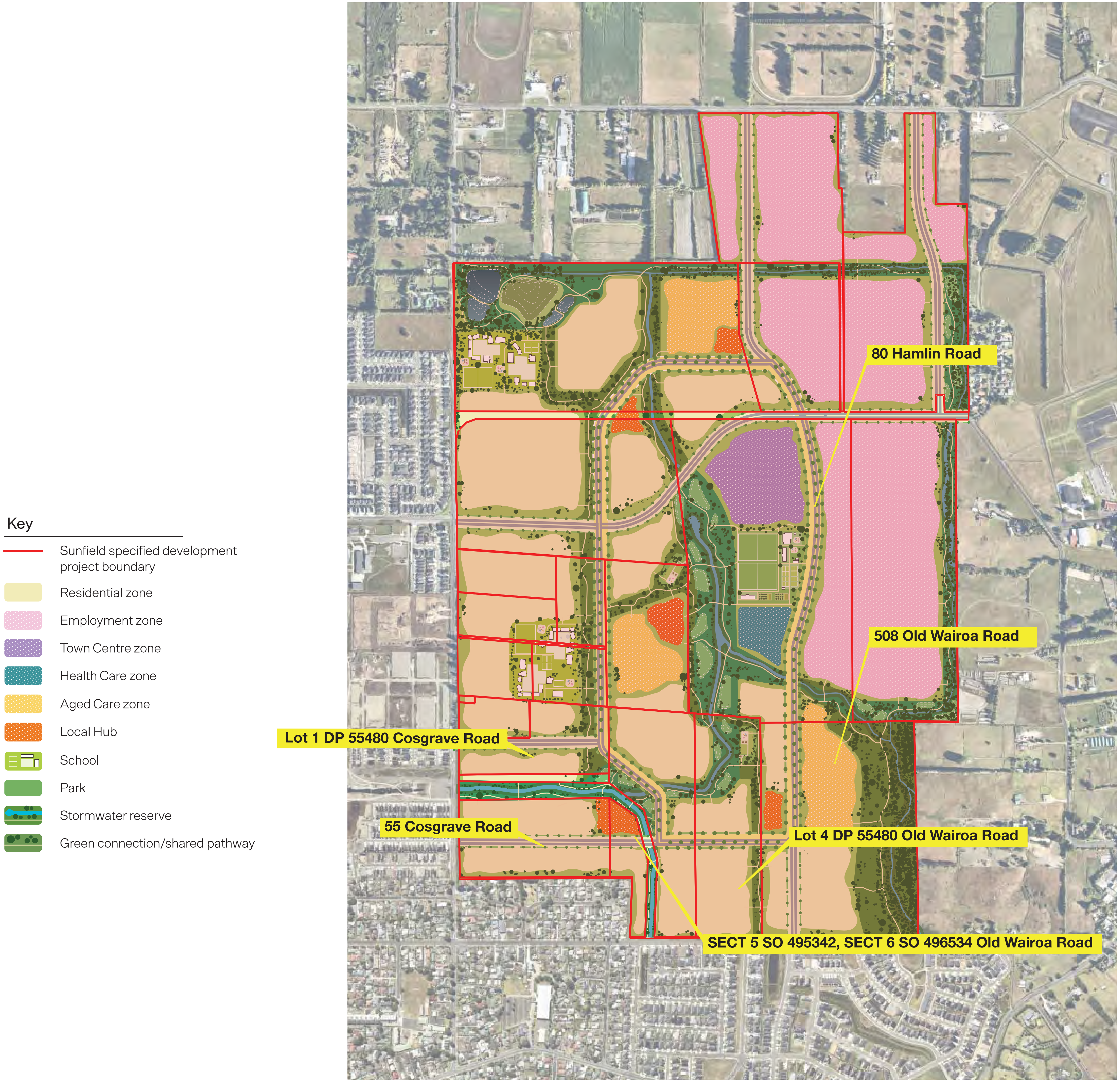
Key

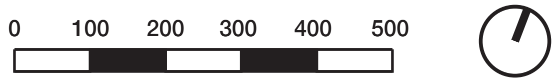
- Sunfield specified development project boundary
- Residential zone
- Employment zone
- Town Centre zone
- Health Care zone
- Aged Care zone
- Local Hub
- School
- Park
- Stormwater reserve
- Green connection/shared pathway

0 100 200 300 400 500

Sunfield Masterplanned Community

Property Titles Overlay - 29.11.2023





Notes

1. BEARING AND COORDINATE DATUM IS NZGD2000 MOUNT EDEN CIRCUIT 2000 LEVELS ARE IN TERMS OF LANDS AND SURVEY DATUM (MSL) AUCKLAND 1946.
2. ORIGIN OF SURVEY CE 34 (AEE6) 783303.09mN,417353.67mE, RL 24.746m
3. CHECK ORIGIN OF SURVEY SM 5813 (C6AM) (SO 58209) 781995.74mN, 418450.50mE, RL 34.51m

Legend

- EX BDY
- PROP BDY
- EX MAJOR CONTOUR
- EX MINOR CONTOUR
- PR MAJOR CONTOUR
- PR MINOR CONTOUR

Rev	Description	By	Date
C	FOR INFORMATION	CE	12/2023

	By	Date
Survey	BY	MM/YYYY
Design	CE	12/2023
Drawn	CE	12/2023
Checked	WM	12/2023

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Project
SUNFIELD DEVELOPMENT ARDMORE FOR WINTON PROPERTY LTD

Title
PROPOSED BULK EARTHWORKS LEVELS

Project no.	215001
Scale	1:9000 @A3
Cad file	C200-EARTHWORKS SITEWIDE 1.DWG
Drawing no.	C200
Rev	C

EARTH WORKS (SURFACE EXISTING COMPARISON WITH SURFACE PROPOSED BULK EARTHWORKS)
CUT/FILL VOLUMES ARE APPROXIMATE

CUT VOLUME	830,000 m³
FILL VOLUME	830,000 m³
CUT TO FILL BALANCE	0,00 m³

NOTE: NO ALLOWANCE FOR SERVICES TRENCHES, VOLUMES ARE UNFACTORED AND IN SITU

Notes

1. BEARING AND COORDINATE DATUM IS NZGD2000 MOUNT EDEN CIRCUIT 2000 LEVELS ARE IN TERMS OF LANDS AND SURVEY DATUM (MSL) AUCKLAND 1946.
2. ORIGIN OF SURVEY CE 34 (AEE6) 783303.09mN,417353.67mE, RL 24.746m
3. CHECK ORIGIN OF SURVEY SM 5813 (C6AM) (SO 58209) 781995.74mN, 418450.50mE, RL 34.51m

LEGEND

EX BDY
PROP BDY
PROP EXTENT WORK

Cut/Fill Table

Number #	Minimum Elevation	Maximum Elevation	Color
1	-6.277	-1.000	
2	-1.000	-0.500	
3	-0.500	0.000	
4	0.000	0.500	
5	0.500	1.000	
6	1.000	1.500	
7	1.500	2.000	
8	2.000	2.968	

Rev	Description	By	Date
C	FOR INFORMATION	CE	12/2023

	By	Date
Survey	BY	MM/YYYY
Design	CE	12/2023
Drawn	CE	12/2023
Checked	WM	12/2023

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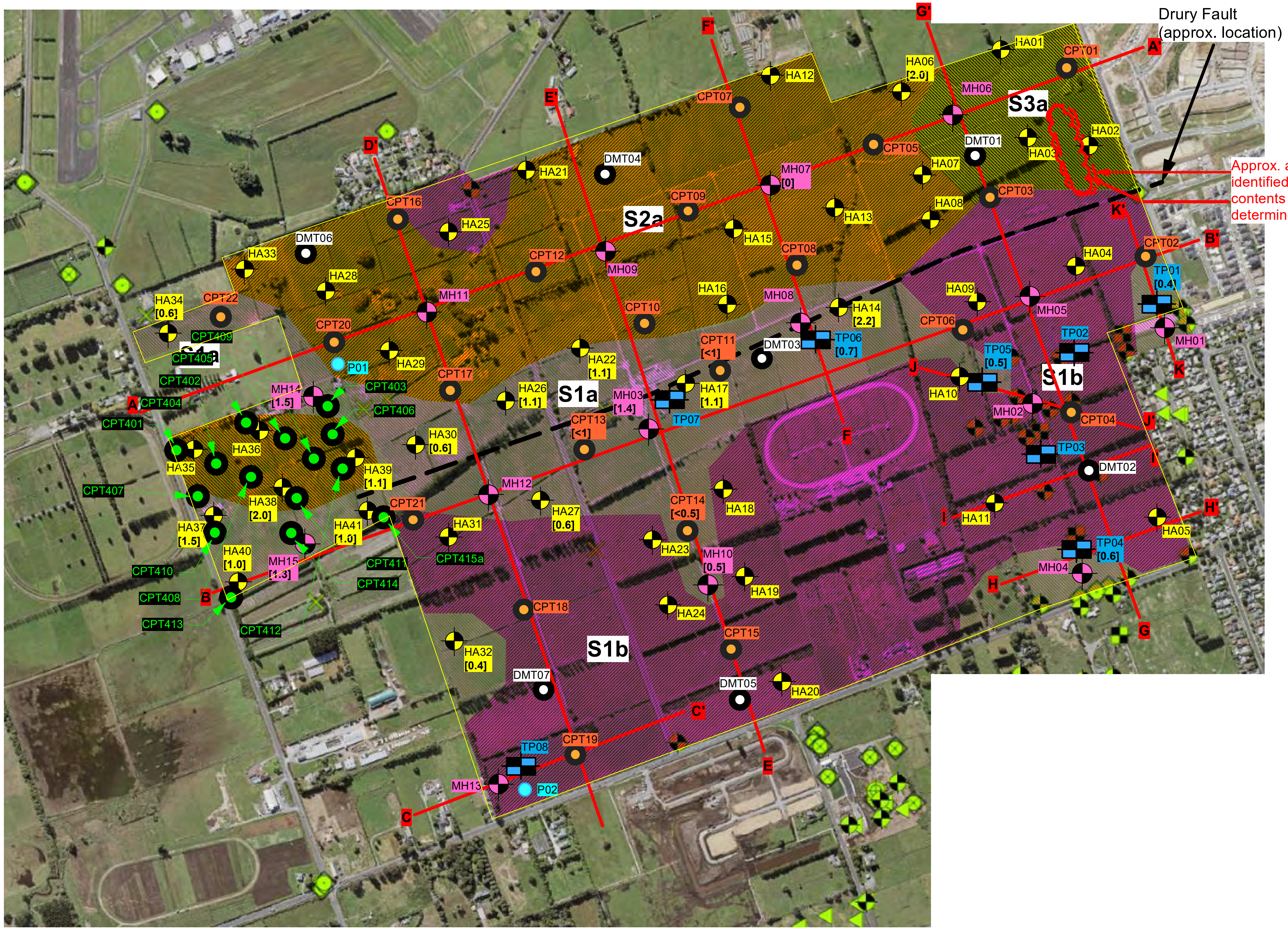
Project
SUNFIELD DEVELOPMENT ARDMORE FOR WINTON PROPERTY LTD

Title
PROPOSED BULK EARTHWORKS CUT TO FILL PLAN

Project no.	215001
Scale	1:9000 @A3
Cad file	C200-EARTHWORKS SITEWIDE 1.DWG
Drawing no.	C201
Rev	C

Appendix 2
Lander Geotechnical Consultants Limited and LDE Limited Drawings



Legend and/or Notes:

- Trial Pit (TP) [Lander 2021]
- Machine Borehole (MH) [Lander 2021]
- Cone Penetration Test (CPT) [Lander 2021]
- Dilatometer Test (DMT) [Lander 2021]
- Hand Auger Borehole (HA) [Lander 2021]
- Falling Head Percolation Test [Lander 2021]
- Cone Penetration Test (CPT) [Initia 2022]
- Study Area
- Geotechnical Cross Section Alignment

- **S1a - Zone 1: Crust material** *(Undifferentiated Alluvium; Q1al).*
- **S1b - Zone 1: Peat** *(Undifferentiated Alluvium; Q1al)*
- **S2a - Zone 2: Overconsolidated Clays/Silts (Upper)** *(Puketoka Formation; Pup)*
- **S3a - Zone 2: Residual Clays/Silts** *(East Coast Bays Formation; Mwe)*

THICKNESS OF INORGANIC CRUST INDICATED IN [BRACKETS] IN METRES. ALL TESTS IN S1b MATERIALS HAVE 0m CRUST THICKNESS.

Green circles and crosses are various existing tests from NZGS database

SOURCE: NZGS Database, existing tests as green circles or crosses

revision	description	drawn	approved	date

0 200.0 400.0 600.0
Horizontal Scale (metres)

0 200.0 400.0 600.0
Vertical Scale (metres)

drawn	KM
approved	SGL
date	28.11.23
scale	1:10,000
original size	A3

LAND DEVELOPMENT & ENGINEERING

client:	SUNFIELD DEVELOPMENTS LIMITED
project:	SUNFIELDS, ARDMORE
title:	STUDY AREA GEOLOGY PLAN
project no: J01627	figure no: 2.1

Template revision: 1:1000 (10/12/14)

Legend and/or Notes:

SOURCE: NZGS Database, existing tests as green circles or crosses

Green circles and crosses are various existing tests from NZGS database

MEASURED GROUNDWATER LEVELS WITHIN STANDPIPES ON MONITORING DATES INDICATED IN [BRACKETS]

revision	description	drawn	approved	date

0 200.0 400.0 600.0
Horizontal Scale (metres)
0 200.0 400.0 600.0
Vertical Scale (metres)

drawn	KM
approved	SGL
date	28.11.23
scale	1:10,000
original size	A3

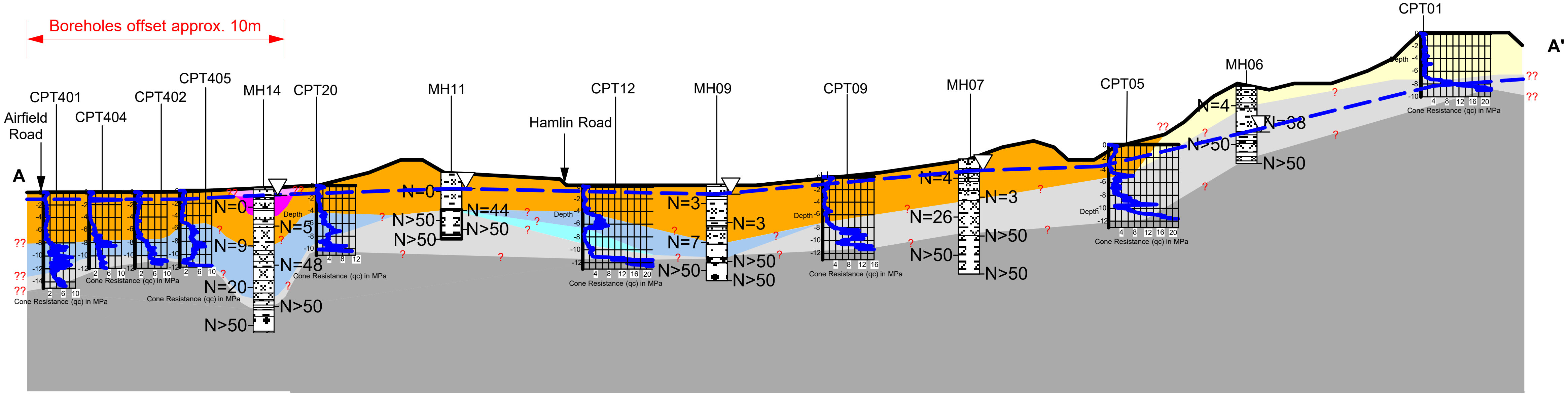
client: **SUNFIELD DEVELOPMENTS LIMITED**

project: **SUNFIELDS, ARDMORE**

title: **SEASONAL STANDPIPE GROUNDWATER LEVELS**

project no: **J01627** figure no: **2.2**

Template revision: 1:1000 (10/12/14)



Legend and/or Notes:

S1a - Zone 1: Crust material *(Undifferentiated Alluvium; Q1al)*

S1b - Zone 1: Peat *(Undifferentiated Alluvium; Q1al)*

S2a - Zone 2: Overconsolidated Clays/Silts (Upper) *(Puketoka Formation; Pup)*

S2b - Zone 1: Normally Consolidated Clays *(Puketoka Formation; Pup)*

S2c - Zone 1: Loose Sands/Dilatant Silts *(Puketoka Formation; Pup)*

S2d - Zone 1: Overconsolidated Clays/Silts (Lower) *(Puketoka Formation; Pup)*

S3a - Zone 2: Residual Clays/Silts *(East Coast Bays Formation; Mwe)*

S3b - Zone 2: Transitional Clays/Silts *(East Coast Bays Formation; Mwe)*

S3c - Zone 2: Bedrock *(East Coast Bays Formation; Mwe)*

Groundwater Table

revision	description	drawn	approved	date

0 120.0 240.0 360.0 480.0
Horizontal Scale (metres)

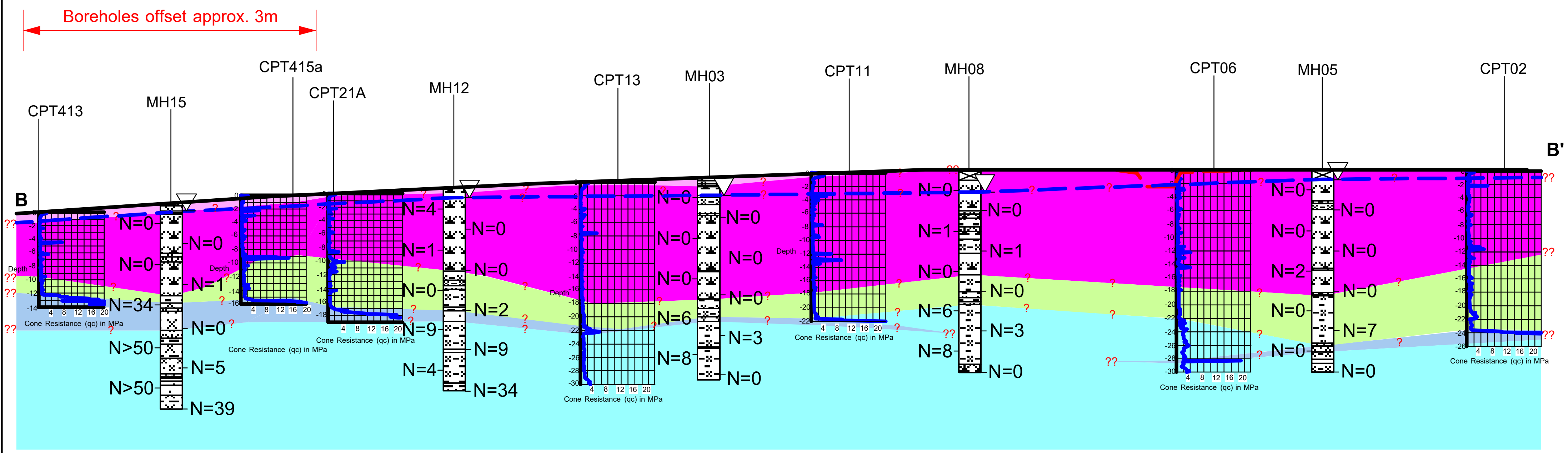
0 12.0 24.0 36.0 48.0
Vertical Scale (metres)

drawn	JM
approved	SGL
date	13.02.23
scale	1:8000
original size	A3

LAND DEVELOPMENT & ENGINEERING

client:	SUNFIELD DEVELOPMENTS LIMITED		
project:	SUNFIELDS, ARDMORE		
title:	CROSS SECTION AA'		
project no:	J01627	figure no:	2.3

Template revision: 1:2000 (10/12/14)



Legend and/or Notes:

- **S1a - Zone 1: Crust material** *(Undifferentiated Alluvium; Q1al)*
- **S1b - Zone 1: Peat** *(Undifferentiated Alluvium; Q1al)*
- **S2a - Zone 2: Overconsolidated Clays/Silts (Upper)** *(Puketoka Formation; Pup)*
- **S2b - Zone 1: Normally Consolidated Clays** *(Puketoka Formation; Pup)*
- **S2c - Zone 1: Loose Sands/Dilatant Silts** *(Puketoka Formation; Pup)*
- **S2d - Zone 1: Overconsolidated Clays/Silts (Lower)** *(Puketoka Formation; Pup)*
- **S3a - Zone 2: Residual Clays/Silts** *(East Coast Bays Formation; Mwe)*
- **S3b - Zone 2: Transitional Clays/Silts** *(East Coast Bays Formation; Mwe)*
- **S3c - Zone 2: Bedrock** *(East Coast Bays Formation; Mwe)*
- **Groundwater Table**

revision	description	drawn	approved	date

0 120.0 240.0 360.0 480.0
Horizontal Scale (metres)

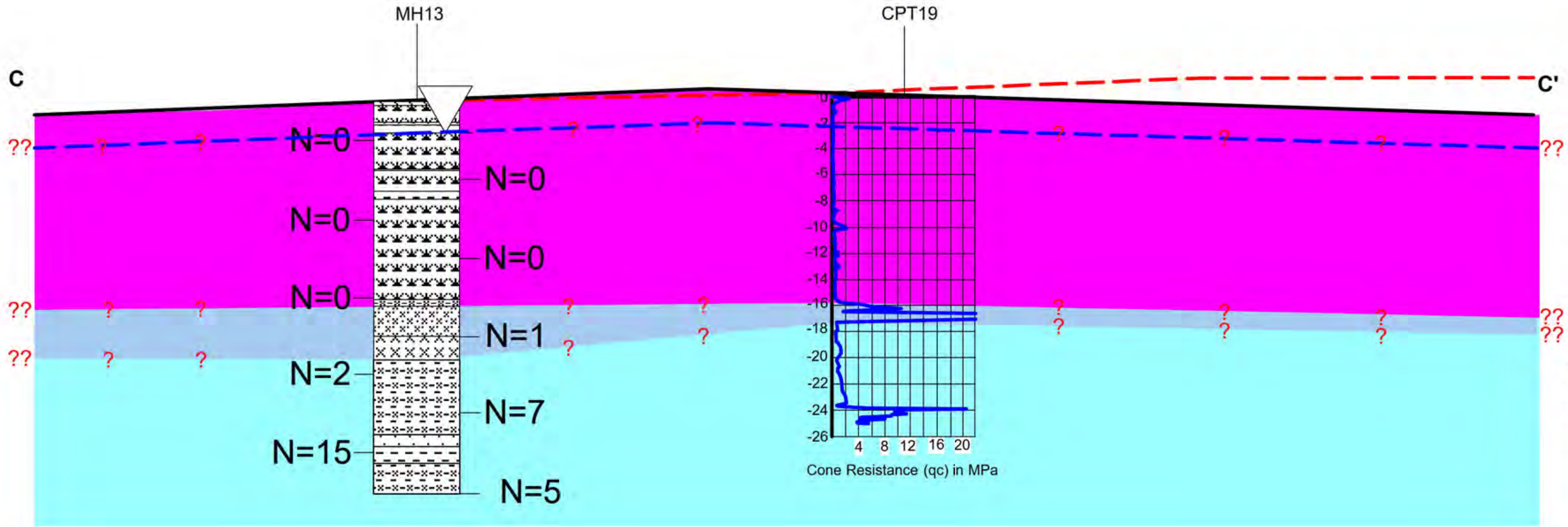
0 12.0 24.0 36.0 48.0
Vertical Scale (metres)

drawn	JM
approved	SGL
date	13.02.23
scale	1:8000
original size	A3

LAND DEVELOPMENT & ENGINEERING

client:	SUNFIELD DEVELOPMENTS LIMITED
project:	SUNFIELDS, ARDMORE
title:	CROSS SECTION BB'
project no: J01627	figure no: 2.4

Template revision: 1:2000 (10/12/14)



Legend and/or Notes:

- **S1a - Zone 1: Crust material** *(Undifferentiated Alluvium; Q1al)*
- **S1b - Zone 1: Peat** *(Undifferentiated Alluvium; Q1al)*
- **S2a - Zone 2: Overconsolidated Clays/Silts (Upper)** *(Puketoka Formation; Pup)*
- **S2b - Zone 1: Normally Consolidated Clays** *(Puketoka Formation; Pup)*
- **S2c - Zone 1: Loose Sands/Dilatant Silts** *(Puketoka Formation; Pup)*
- **S2d - Zone 1: Overconsolidated Clays/Silts (Lower)** *(Puketoka Formation; Pup)*
- **S3a - Zone 2: Residual Clays/Silts** *(East Coast Bays Formation; Mwe)*
- **S3b - Zone 2: Transitional Clays/Silts** *(East Coast Bays Formation; Mwe)*
- **S3c - Zone 2: Bedrock** *(East Coast Bays Formation; Mwe)*
- **Groundwater Table**
- **Proposed Ground Level**

revision	description	drawn	approved	date

0 30.0 60.0 90.0 120.0
Horizontal Scale (metres)

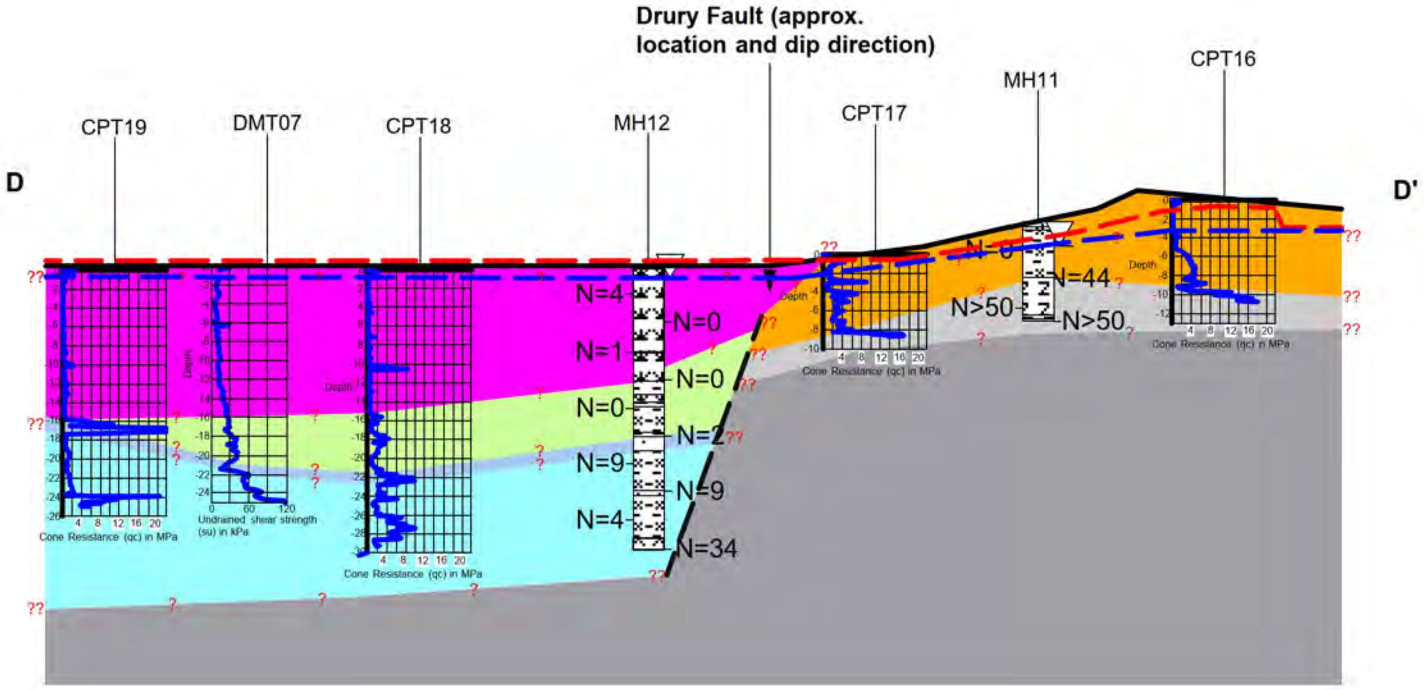
0 6.0 12.0 18.0 24.0
Vertical Scale (metres)

drawn	PL
approved	SGL
date	03.06.21
scale	1:8000
original size	A3

LANDER geotechnical

client:	SUNFIELD DEVELOPMENTS LIMITED
project:	SUNFIELDS, ARDMORE
title:	CROSS SECTION CC'
project no:	J01627
figure no:	2.5

Template revision: 1:2000 (10/12/14)



Legend and/or Notes:

- **S1a - Zone 1: Crust material** *(Undifferentiated Alluvium; Q1al)*
- **S1b - Zone 1: Peat** *(Undifferentiated Alluvium; Q1al)*
- **S2a - Zone 2: Overconsolidated Clays/Silts (Upper)** *(Puketoka Formation; Pup)*
- **S2b - Zone 1: Normally Consolidated Clays** *(Puketoka Formation; Pup)*
- **S2c - Zone 1: Loose Sands/Dilatant Silts** *(Puketoka Formation; Pup)*
- **S2d - Zone 1: Overconsolidated Clays/Silts (Lower)** *(Puketoka Formation; Pup)*
- **S3a - Zone 2: Residual Clays/Silts** *(East Coast Bays Formation; Mwe)*
- **S3b - Zone 2: Transitional Clays/Silts** *(East Coast Bays Formation; Mwe)*
- **S3c - Zone 2: Bedrock** *(East Coast Bays Formation; Mwe)*
- **Groundwater Table**
- **Proposed Ground Level**

revision	description	drawn	approved	date

Horizontal Scale (metres): 0, 120.0, 240.0, 360.0, 480.0

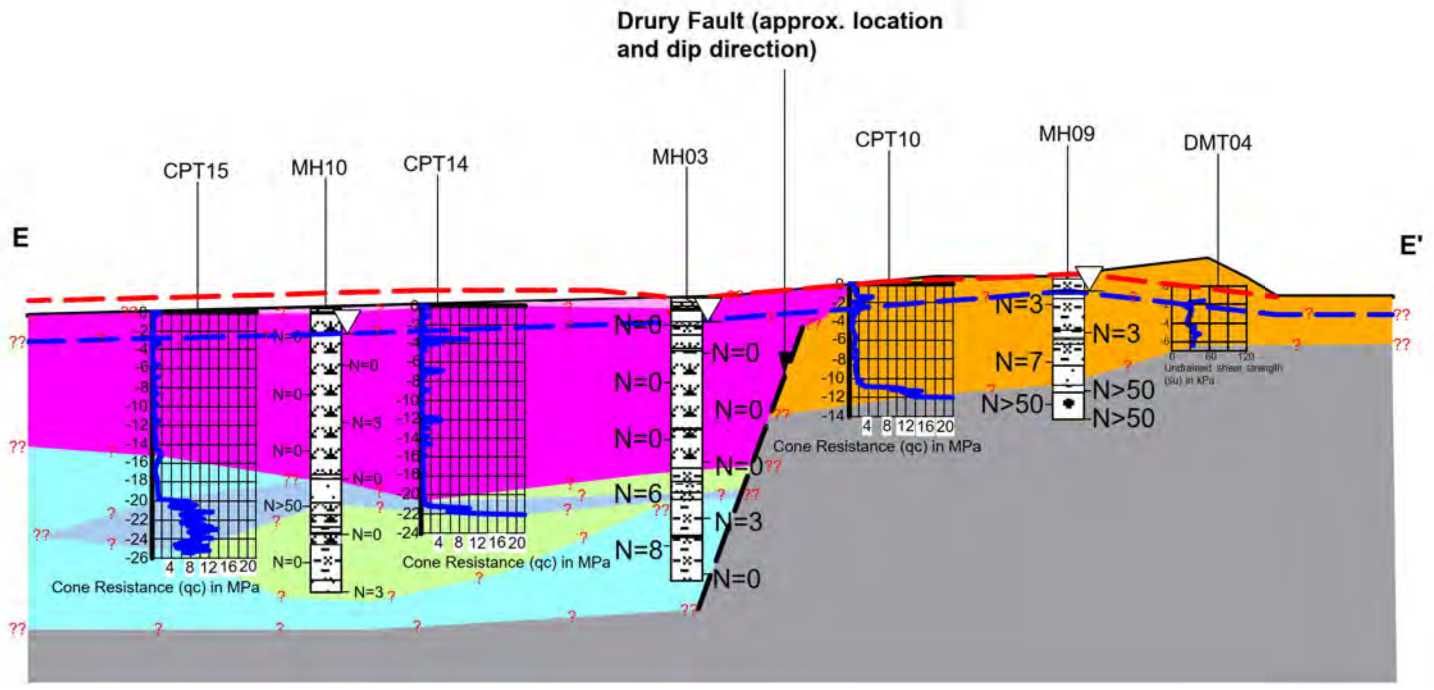
Vertical Scale (metres): 0, 12.0, 24.0, 36.0, 48.0

drawn	PL
approved	SGL
date	03.06.21
scale	1:8000
original size	A3

LANDER geotechnical

client:	SUNFIELD DEVELOPMENTS LIMITED
project:	SUNFIELDS, ARDMORE
title:	CROSS SECTION DD'
project no:	J01627
figure no:	2.6

Template revision: 1:2000 (10/12/14)



Legend and/or Notes:

- **S1a - Zone 1: Crust material** *(Undifferentiated Alluvium; Q1al)*
- **S1b - Zone 1: Peat** *(Undifferentiated Alluvium; Q1al)*
- **S2a - Zone 2: Overconsolidated Clays/Silts (Upper)** *(Puketoka Formation; Pup)*
- **S2b - Zone 1: Normally Consolidated Clays** *(Puketoka Formation; Pup)*
- **S2c - Zone 1: Loose Sands/Dilatant Silts** *(Puketoka Formation; Pup)*
- **S2d - Zone 1: Overconsolidated Clays/Silts (Lower)** *(Puketoka Formation; Pup)*
- **S3a - Zone 2: Residual Clays/Silts** *(East Coast Bays Formation; Mwe)*
- **S3b - Zone 2: Transitional Clays/Silts** *(East Coast Bays Formation; Mwe)*
- **S3c - Zone 2: Bedrock** *(East Coast Bays Formation; Mwe)*
- **Groundwater Table**
- **Proposed Ground Level**

revision	description	drawn	approved	date

Horizontal Scale (metres): 0, 120.0, 240.0, 360.0, 480.0

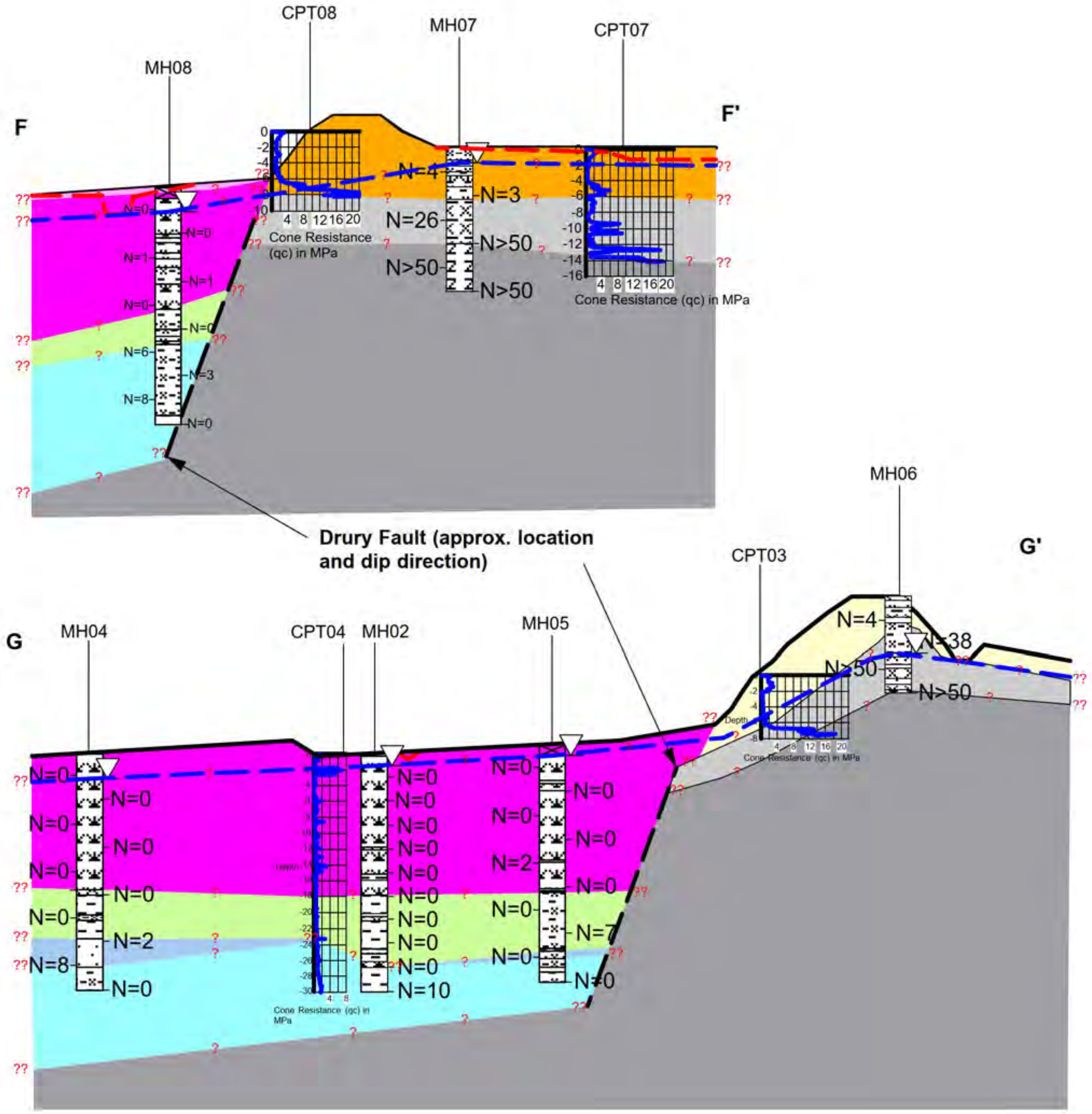
Vertical Scale (metres): 0, 12.0, 24.0, 36.0, 48.0

drawn	PL
approved	SGL
date	04.06.21
scale	1:8000
original size	A3

LANDER geotechnical

client:	SUNFIELD DEVELOPMENTS LIMITED
project:	SUNFIELDS, ARDMORE
title:	CROSS SECTION EE'
project no:	J01627
figure no:	2.7

Template revision: 1:2000 (10/12/14)



Legend and/or Notes:

S1a - Zone 1: Crust material *(Undifferentiated Alluvium; Q1al)*

S1b - Zone 1: Peat *(Undifferentiated Alluvium; Q1al)*

S2a - Zone 2: Overconsolidated Clays/Silts (Upper) *(Puketoka Formation; Pup)*

S2b - Zone 1: Normally Consolidated Clays *(Puketoka Formation; Pup)*

S2c - Zone 1: Loose Sands/Dilatant Silts *(Puketoka Formation; Pup)*

S2d - Zone 1: Overconsolidated Clays/Silts (Lower) *(Puketoka Formation; Pup)*

S3a - Zone 2: Residual Clays/Silts *(East Coast Bays Formation; Mwe)*

S3b - Zone 2: Transitional Clays/Silts *(East Coast Bays Formation; Mwe)*

S3c - Zone 2: Bedrock *(East Coast Bays Formation; Mwe)*

Groundwater Table

Proposed Ground Level

revision	description	drawn	approved	date

0 120.0 240.0 360.0 480.0
Horizontal Scale (metres)

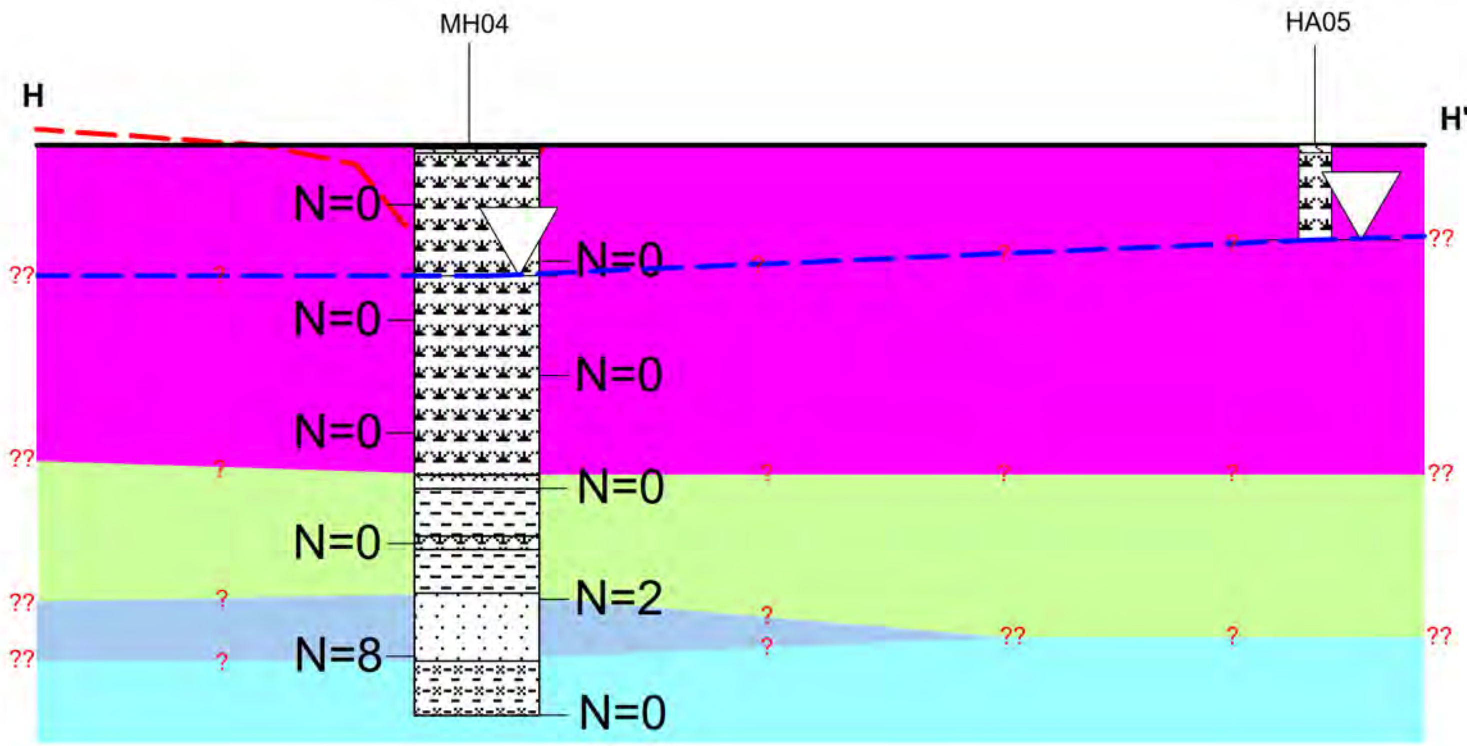
0 12.0 24.0 36.0 48.0
Vertical Scale (metres)

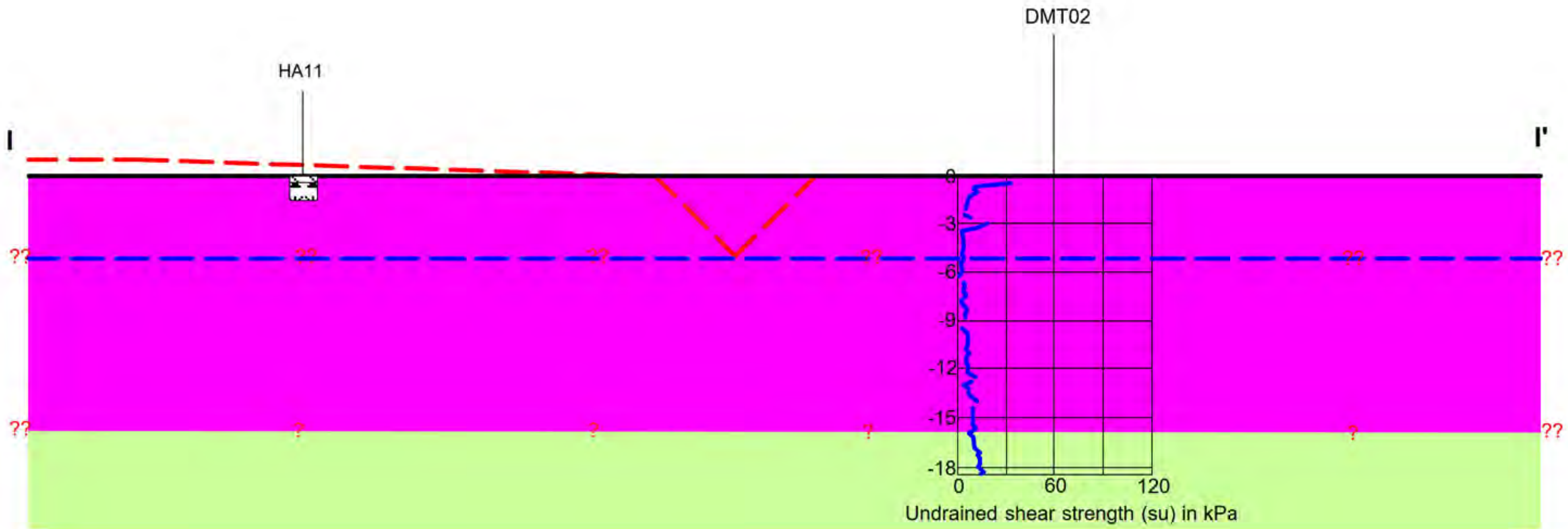
drawn	PL
approved	SGL
date	04.06.21
scale	1:8000
original size	A3

LANDER geotechnical

client:	SUNFIELD DEVELOPMENTS LIMITED		
project:	SUNFIELDS, ARDMORE		
title:	CROSS SECTION FF' & GG'		
project no:	J01627	figure no:	2.8

Template revision: 1:2000 (10/12/14)





Legend and/or Notes:

- **S1a - Zone 1: Crust material** *(Undifferentiated Alluvium; Q1al)*
- **S1b - Zone 1: Peat** *(Undifferentiated Alluvium; Q1al)*
- **S2a - Zone 2: Overconsolidated Clays/Silts (Upper)** *(Puketoka Formation; Pup)*
- **S2b - Zone 1: Normally Consolidated Clays** *(Puketoka Formation; Pup)*
- **S2c - Zone 1: Loose Sands/Dilatant Silts** *(Puketoka Formation; Pup)*
- **S2d - Zone 1: Overconsolidated Clays/Silts (Lower)** *(Puketoka Formation; Pup)*
- **S3a - Zone 2: Residual Clays/Silts** *(East Coast Bays Formation; Mwe)*
- **S3b - Zone 2: Transitional Clays/Silts** *(East Coast Bays Formation; Mwe)*
- **S3c - Zone 2: Bedrock** *(East Coast Bays Formation; Mwe)*
- **Groundwater Table**
- **Proposed Ground Level**

revision	description	drawn	approved	date

0 30.0 60.0 90.0 120.0
Horizontal Scale (metres)

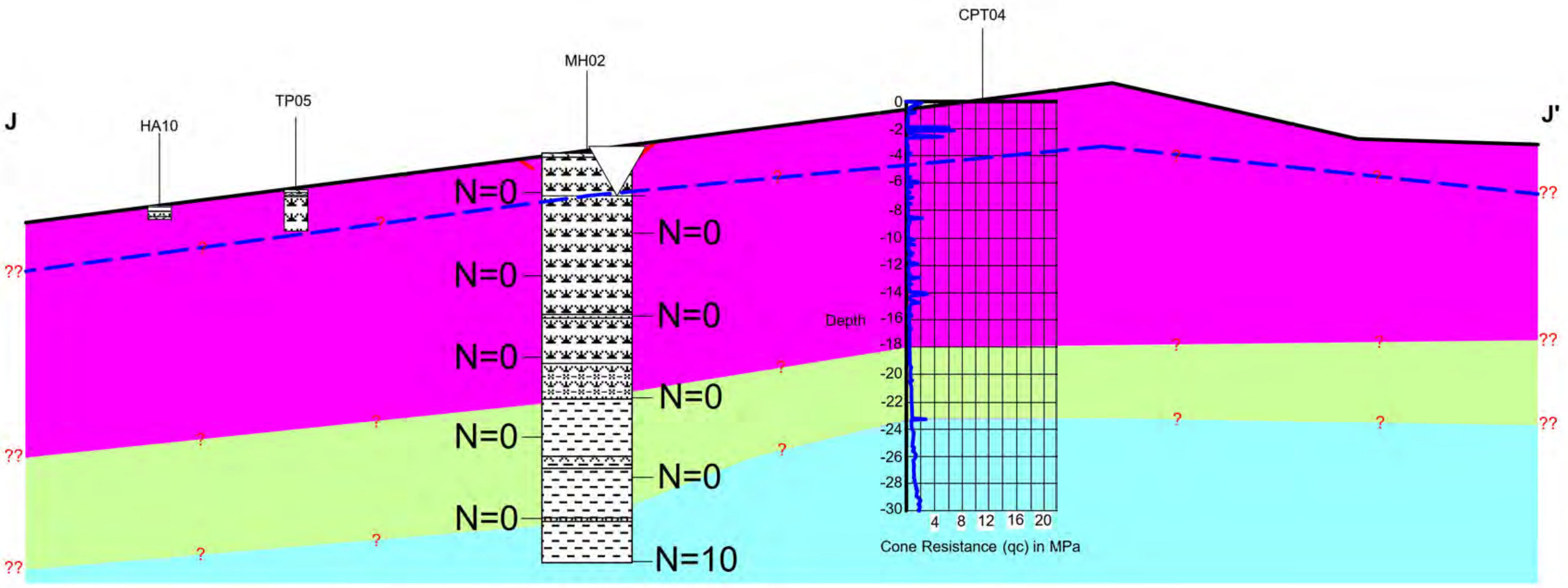
0 6.0 12.0 18.0 24.0
Vertical Scale (metres)

drawn	PL
approved	SGL
date	03.06.21
scale	1:2000
original size	A3

LANDER geotechnical

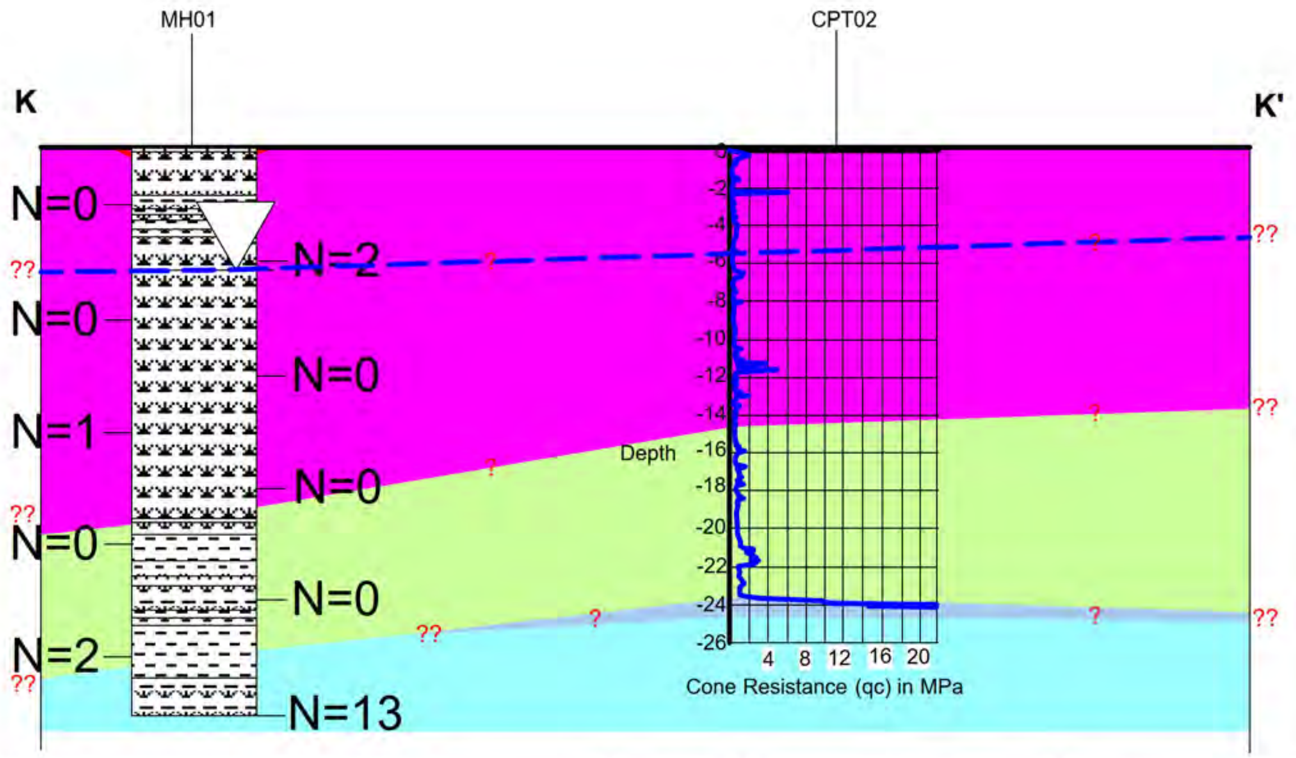
client:	SUNFIELD DEVELOPMENTS LIMITED
project:	SUNFIELDS, ARDMORE
title:	CROSS SECTION HH' & II'
project no: J01627	figure no: 2.9

Template revision: 1:2000 (10/12/14)



Legend and/or Notes:

- **S1a - Zone 1: Crust material** *(Undifferentiated Alluvium; Q1al)*
- **S1b - Zone 1: Peat** *(Undifferentiated Alluvium; Q1al)*
- **S2a - Zone 2: Overconsolidated Clays/Silts (Upper)** *(Puketoka Formation; Pup)*
- **S2b - Zone 1: Normally Consolidated Clays** *(Puketoka Formation; Pup)*
- **S2c - Zone 1: Loose Sands/Dilatant Silts** *(Puketoka Formation; Pup)*
- **S2d - Zone 1: Overconsolidated Clays/Silts (Lower)** *(Puketoka Formation; Pup)*
- **S3a - Zone 2: Residual Clays/Silts** *(East Coast Bays Formation; Mwe)*
- **S3b - Zone 2: Transitional Clays/Silts** *(East Coast Bays Formation; Mwe)*
- **S3c - Zone 2: Bedrock** *(East Coast Bays Formation; Mwe)*
- **Groundwater Table**
- **Proposed Ground Level**



revision	description	drawn	approved	date

0 30.0 60.0 90.0 120.0
Horizontal Scale (metres)

0 6.0 12.0 18.0 24.0
Vertical Scale (metres)

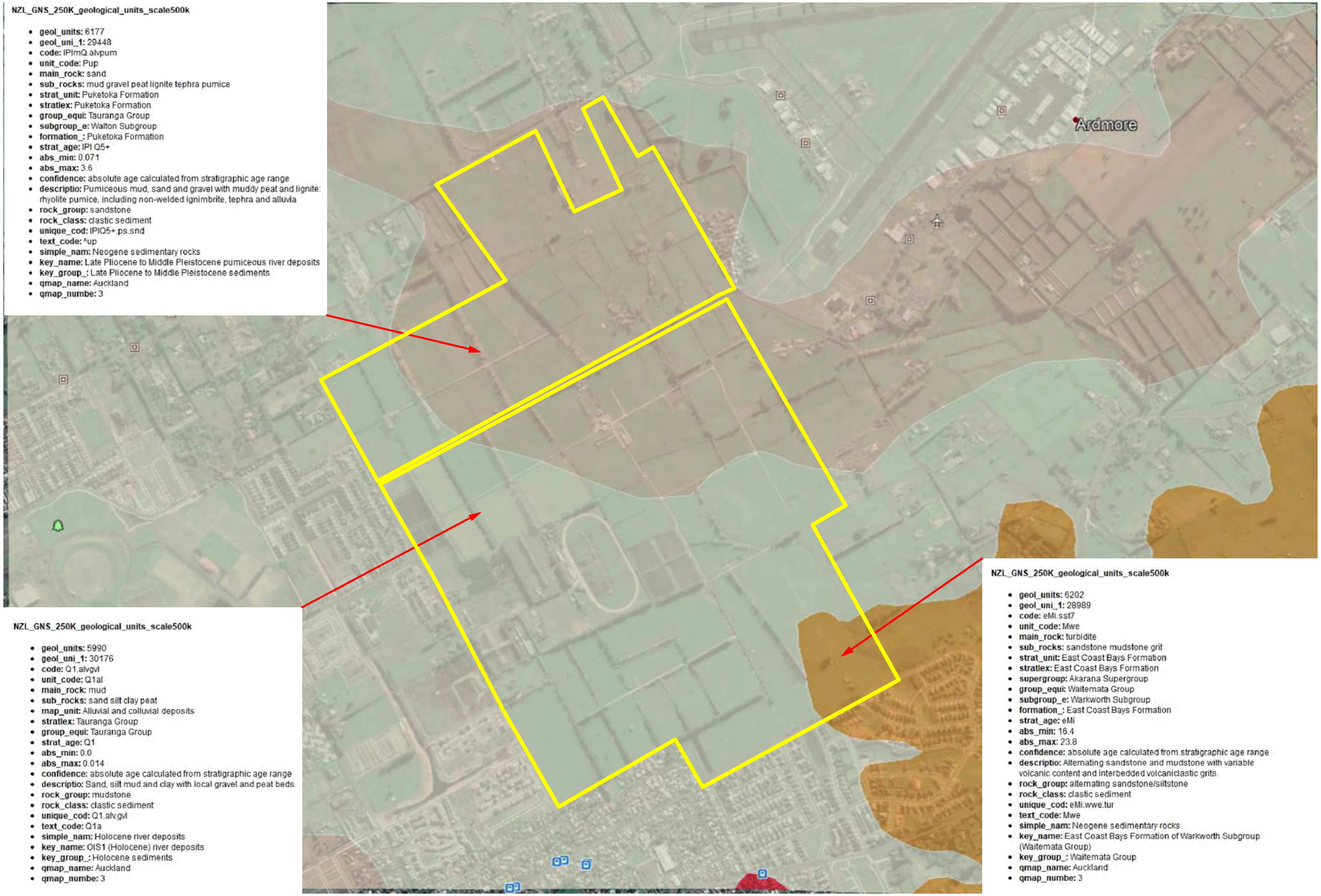
drawn	PL
approved	SGL
date	03.06.21
scale	1:2000
original size	A3

LANDER geotechnical

client:	SUNFIELD DEVELOPMENTS LIMITED
project:	SUNFIELDS, ARDMORE
title:	CROSS SECTION JJ' & KK'
project no: J01627	figure no: 2.10

Template revision: 1:2000 (10/12/14)

Legend and/or Notes:



revision	description	drawn	approved	date

drawn	KM
approved	SGL
date	28.11.23
scale	nts
original size	A3

LAND DEVELOPMENT & ENGINEERING

client:	SUNFIELD DEVELOPMENT LIMITED
project:	SUNFIELDS, ARDMORE
title:	GEOLOGY
project no: J01627	figure no: 2.11

Template revision: 1:1000 (10/12/14)

Legend and/or Notes:

revision	description	drawn	approved	date

drawn	KM
approved	SGL
date	28.11.23
scale	nts
original size	A3

LDE LAND DEVELOPMENT & ENGINEERING

client: SUNFIELD DEVELOPMENTS LIMITED

project: SUNFIELDS, ARDMORE

title: PROXIMITY TO ACTIVE FAULTS

project no: J01627 figure no: 2.12

Sunfields Study Area

0 70 140 210
Meters

Scale @ A3
= 1:8,000

Date Printed:
28/11/2023

Auckland Council
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Map

Wastewater
Local Network
Wastewater Pipe GIS ID Label (Local)
Wastewater Pipe GIS ID Label (Local)
Wastewater Pipe (Local)
Operational
Operational Not Vested
Abandoned / Not Operational
Wastewater Structure (Local)
Wastewater Other Structure (Local)
Wastewater Other Structure (Local)
Wastewater Pump Station (Local)
Wastewater Pump Station (Local)
Transmission Network
Wastewater Pipe (Transmission)
Operational
Operational Not Vested
Abandoned/ Not Operational
Wastewater Structure (Transmission)
Stormwater
Stormwater Treatment Device
Public
Private
Stormwater Pond or Wetland Components
Stormwater Forebay
Public
Private
Stormwater Treatment Facility
Public
Private
Stormwater Watercourse
Public
Private
Stormwater Pipe SAP ID label
Stormwater Pipe SAP ID label

Stormwater Pipe
Public - Gravity Mains
Private - Gravity Mains
KiwiRail, Gravity Mains
Public - Culvert/Tunnel
Private - Culvert/Tunnel
KiwiRail, Culvert/Tunnel; KiwiRail, In Service, Culvert
Public - Rising Main
Private - Rising Main
Public - Subsoil Drain
Private - Subsoil Drain
Stormwater Connection
Public
Private
Stormwater Channel
Public lined
Public Watercourse
Private Watercourse
Stormwater Pump Station
Public
Private
Stormwater Planting
Public
Private
Stormwater Erosion And Flood Control
Public - Wall Structure
Private - Wall Structure
Public - Other Structure
Private - Other Structure
Stormwater Abandoned Assets
Stormwater Abandoned Pipe
Public - Gravity Mains
Public - Culvert/Tunnel

Public - Rising Main
Public - Subsoil Drain
Stormwater Abandoned Connection
Public
Septic Tank
Public - Hi-Tech
Private - Hi-Tech
Public - Other
Private - Other
Stormwater GPS
GPS Location (NorthShore)
GPS Location (NorthShore)
GPS Survey (North Shore)
GPS Survey (North Shore)
Water
Local Network
Water Pipe (Local)
Operational (Non-Potable)
Operational (Potable)
Operational Not Vested
Abandoned / Not Operational
Water Structure (Local)
Water Other Structure (Local)
Water Other Structure (Local)
Water Pump Station (Local)
Water Pump Station (Local)
Water Reservoir (Local)
Water Reservoir (Local)
Transmission Network
Water Fitting (Transmission)
Water Pipe (Transmission)
Operational (Non-Potable)
Operational (Potable)
Not Operational
Proposed

Water Structure (Transmission)
Water Reservoir (Transmission)
Water Reservoir (Transmission)
Water Source (Transmission)
Water Source (Transmission)
Other Watercare Assets
Other Watercare Linear Assets
Other Watercare Linear Assets
Other Watercare Structures and Areas
Other Watercare Structures and Areas
Other Non Watercare
Non Watercare Pipe
Non Watercare Pipe
Asbuilt Area
Asbuilt Area
Transpower
Transpower Pylons
Transpower Pylons
Transpower Sites
Transpower Sites
Electricity Transmission Lines
110 kv
220 kv
400 kv
LGP Pipeline
LGP Pipeline
Aviation JetA1 Fuel Pipeline
Aviation JetA1 Fuel Pipeline
Gas Transmission Lines
Gas Transmission Lines
High Pressure Gas Pipelines
High Pressure Gas Pipelines
Medium-Pressure Gas Pipeline
Medium-Pressure Gas Pipeline
RNZ Liquid Fuels Pipeline Marsden to Wiri
RNZ Liquid Fuels Pipeline Marsden to Wiri

Fibre Optic Cable - ARTA
Fibre Optic Cable - ARTA
Address
Address
Contours 2016
Contours 0m
Contours 0m
Contours 2m Intervals
Contours 100m
Contours 100m
Contours 50m
Contours 50m
Contours 10m
Contours 10m
Contours 2m
Contours 2m
Place Names
Place Name (25,000)
Place Name (25,000)
Public Open Space Names (8,000)
Public Open Space Names (8,000)
Place Name Search
Place Name Search
Rail Stations
Rail Stations (8,000)
Rail Stations (8,000)
Railway Lines
Railway (25,000)
Railway (25,000)
Auckland Council Boundary
Auckland Council Boundary
Roads
Roads (8,000)
Motorway
Motorway Under Construction
Secondary Arterial Road

Secondary Arterial Road Under Construction
Primary Arterial Road
Primary Arterial Road Under Construction
Collector Road
Collector Road Under Construction
Local Road
Local Road Under Construction
Property
Property
Rate Assessment
Rate Assessment
Parcels
Parcels
Coastline
Aerial 2019 2020 Rural
Image
Red: Band_1
Green: Band_2
Blue: Band_3
Aerial 2022 Rural
Image
Red: Band_1
Green: Band_2
Blue: Band_3
Aerial 2017 Urban
Image
Red: Band_1
Green: Band_2
Blue: Band_3
Aerial 2010 2011 Rural
Image
Red: Band_1
Green: Band_2
Blue: Band_3

Legend

Date Printed:
28/11/2023

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