Northlake Investments Limited

Northbrook Retirement Village – Wanaka

Preliminary Stormwater Management Plan

August 2020

Fluent SOLUTIONS

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Northlake Investments Limited

Northbrook Retirement Village – Wanaka
Preliminary Stormwater Management Plan

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Northlake Investments Limited

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1.0 Introduction

Fluent Solutions (FS) has been engaged by Northlake Investments Limited (NIL) to develop a stormwater management concept for the proposed Northbrook Retirement Village (Wanaka) located adjacent to Stage 15 of the Northlake residential development area. The stormwater management concept provided in this report was prepared to support an application for resource consent for the Northbrook Retirement Village.

The Northlake Special Zone encompasses the residential and commercial areas of the Northlake development as well as the proposed Northbrook Retirement Village (located in the Catchment B stormwater management area). Figure 1.1 below shows the location of the proposed Northbrook Retirement Village (Wanaka) as well as the other existing and future development areas within the overall Northlake Catchment B area and part of Catchment A. The stormwater flow paths in Catchments A and B are described in more detail in Section 2.

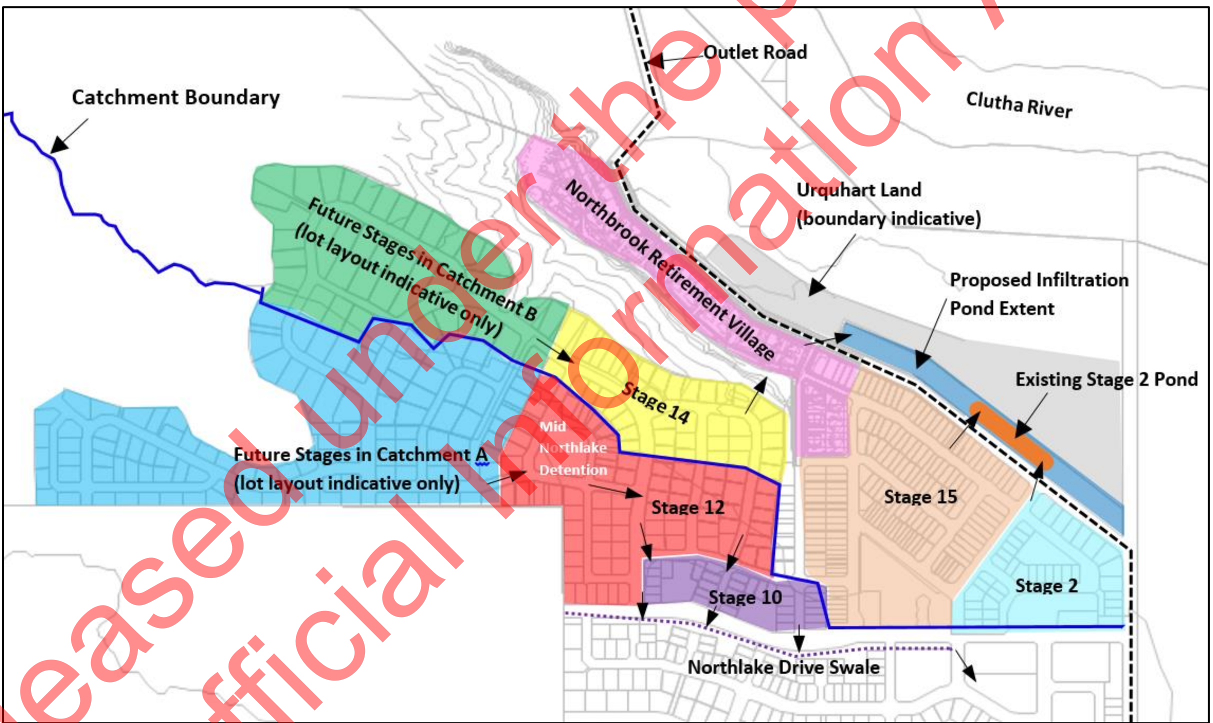


Figure 1.1: Northlake Special Zone Development Areas and Catchment Separation

The stormwater management concept developed for the Northbrook Retirement Village takes into account the existing stormwater management concept developed for the existing development areas as part of a catchment wide approach for Catchment B. Detailed design information for the Northbrook Retirement Village would be provided at the engineering approval application phase.

2.0 Background

2.1 Local Stormwater Catchments

Stormwater within the Northlake Special Zone is managed through two main stormwater catchments referred to as Catchment A and Catchment B. Figure 2.1 below shows the stormwater Sub-catchments in and around the Northlake Special Zone. Specifically, it highlights that the Northbrook Retirement Village is located entirely within Catchment B, with parts in both Sub-catchments B1 and B2.

2.1.1 Catchment A Stormwater Flow Paths

Catchment A is divided into four main Sub-catchments: Upper Northlake, Mid Northlake, Lower Northlake, and the Allenby Farms development areas. Stormwater runoff from the Upper Northlake Sub-catchment flows into the Mid Northlake Sub-catchment where a small detention pond ("Mid Northlake Detention") collects flows and discharges stormwater into the Lower Northlake Sub-catchment via the Stage 10 pipe network.

Within Catchment A, Stage 12 was most recently consented and future stages in Catchment A would be addressed at a later date. There is no stormwater discharge from the Northbrook Retirement Village to Catchment A. The references for Catchment A are for background information only for completeness.

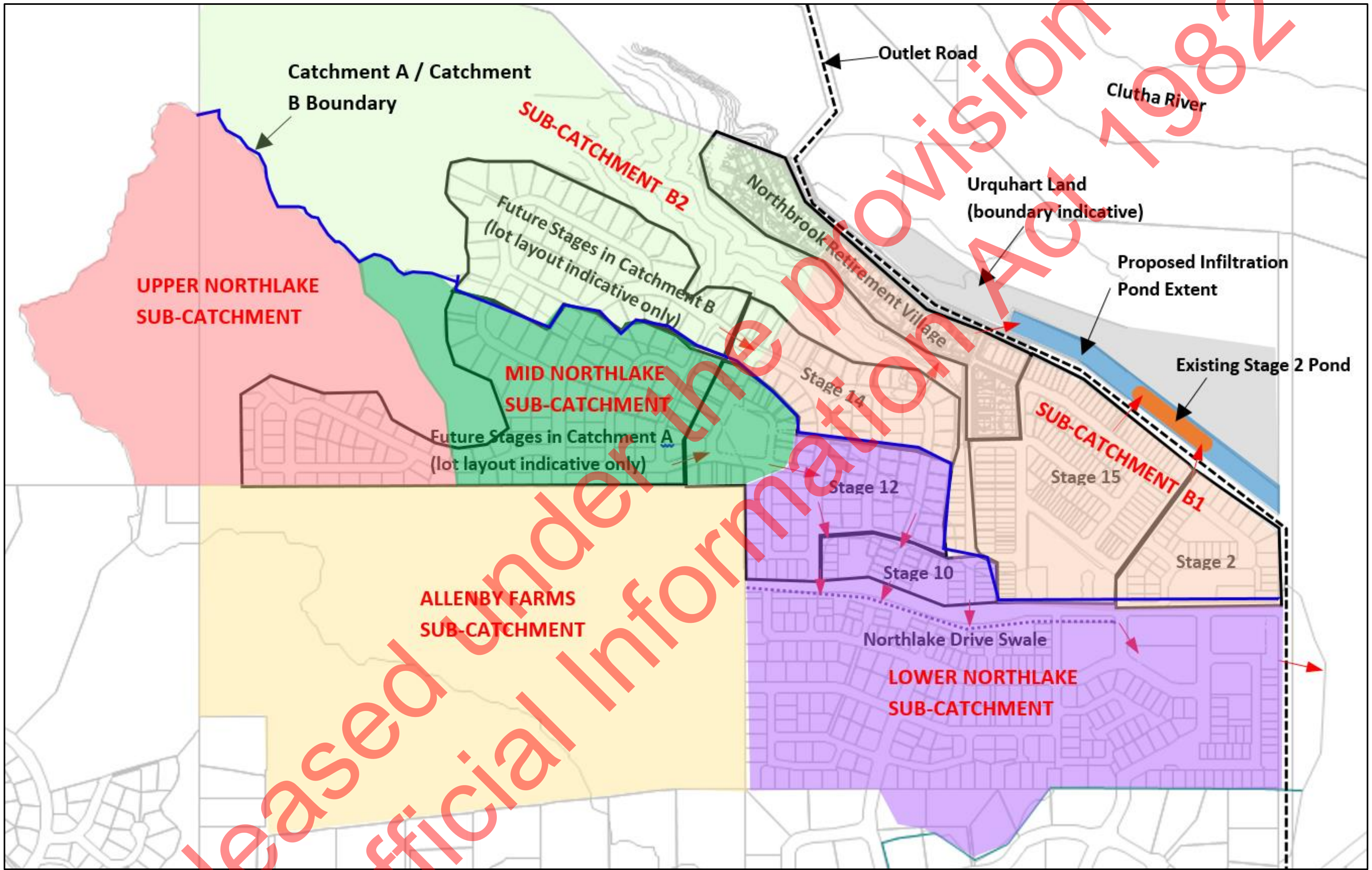


Figure 2.1: Northlake Special Zone Catchment Location Reference (Catchment boundaries and lot layouts are indicative only)

2.1.2 Catchment B Stormwater Flow Paths

Catchment B is the northern area of the Northlake Special Zone. Catchment B is further divided into two Sub-catchments – B1 and B2 as shown in Figure 2.1, which have separate stormwater disposal locations. Sub-catchment B1 naturally drains to soakage in lower lying depressions along Outlet Road, which ultimately discharge to the Clutha River as subsurface flow. Sub-catchment B2 naturally drains via a shallow surface flow path to a small ponding area which then drains via Outlet Road to a well-defined surface flow path to the Clutha River. The extent of Sub-catchments B1 and B2 and the overland flow paths are illustrated in Figure 2.2 below.

The majority of the Northbrook Retirement Village is located in Sub-catchment B1. However, a small portion of the retirement village is located in the Sub-catchment B2, which drains via a surface flow path to the Clutha River. As part of the stormwater management concept, it is proposed to divert the majority of the runoff in the Sub-catchment B2 area into the Sub-catchment B1 drainage to ground. The stormwater management concept is explained in detail in Section 4 below.

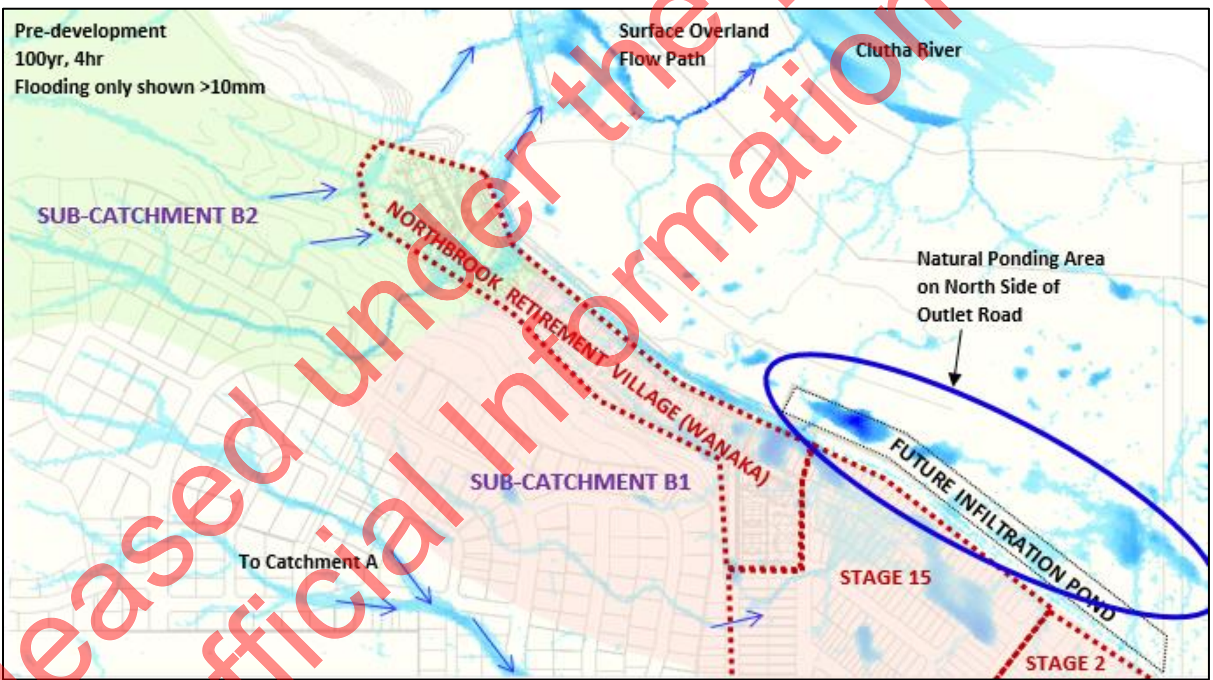


Figure 2.2: Catchment B – Northlake Special Zone Pre-development Flow Paths

Note: The flood extents in Figure 2.2 are for a 100-year Average Recurrence Interval (ARI), 4 hour duration rain event. The lot layout is indicative only.

3.0 Geotechnical Investigations

Geotechnical work was undertaken to quantify the extent of the outwash gravels along the valley floor in the Sub-catchment B2 ponding area along Outlet Road. It is proposed to utilise the natural subsurface outwash gravels in this area for stormwater disposal as the basis for stormwater management in Catchment B. The results of the geotechnical investigation were used to estimate the volume of stormwater, which could be absorbed and conveyed as subsurface flow through the outwash gravels and ultimately discharged to the Clutha River.

The results of the investigation are presented in the Geosolve report "Geotechnical Report for Stormwater Disposal" – Revision 2 dated 28 May 2019, which is included as Appendix 1 to this report.

The results of the geotechnical investigation include a mapped profile of the underlying materials and the infiltration characteristics of the underlying gravels from test pit soakage and permeability testing. The profile of the underlying material consists of:

- A top layer of topsoil and silty sandy subsoils that are generally 0.2 to 1m deep
- Underlain by outwash gravels varying in depth from 3.2 to 7.5m deep
- Overlying glacial till

Test pits and permeability tests were completed and used to determine the hydraulic permeability rate for use in infiltration capacity calculations.

Test pit locations are shown in Figure 3.1 (adopted from the May 2019 Geosolve report). As part of the stormwater management for Catchment B, it is proposed to develop an infiltration pond in the area shaded red in Figure 3.1 (see Section 4 for further detail concerning the stormwater management design).

A summary of the soakage results are set out in Table 1 of the May 2019 Geosolve report and in Figure 3.1 below. Lower soakage rates were observed to the southeast near cross sections I-I' and H-H' and are thought to be due to a higher sand concentration in the soils. Generally, the permeability tests showed reasonable soakage rates.

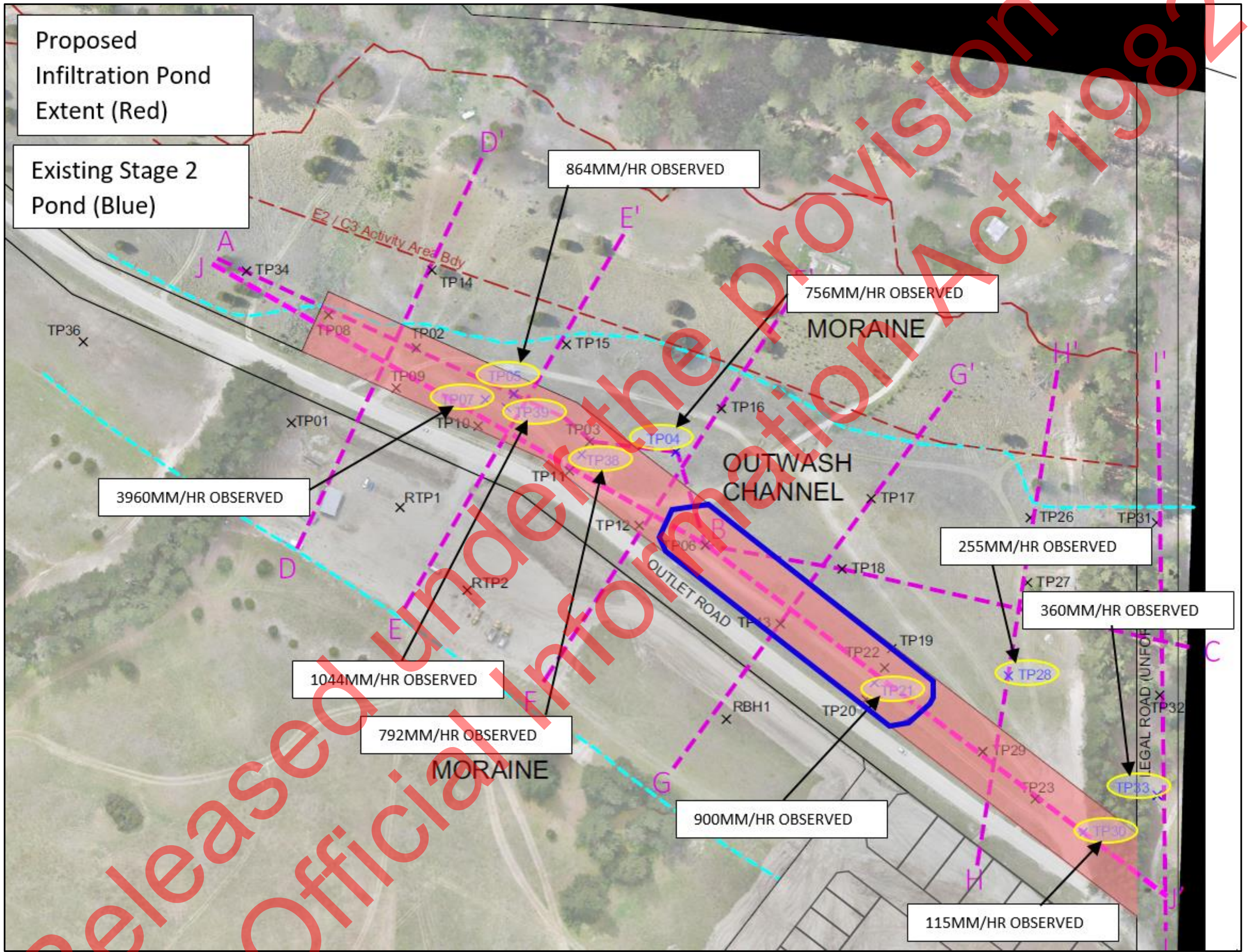


Figure 3.1 Test Pit Locations, Permeability Rates, and Proposed Infiltration Pond Extent

4.0 Northbrook Retirement Village Stormwater Management Concept

4.1 Overview

Stormwater from the Northbrook Retirement Village is proposed to be collected and conveyed to an enlarged stormwater infiltration pond north of Outlet Road for disposal to ground.

Within the retirement village area, stormwater is managed via four conveyance flow paths:

- Generally, stormwater is to be collected and conveyed in a stormwater main draining to the southeast and eventually discharges into the infiltration pond.
- Two swales along the south side of the retirement village are proposed to collect overland flow from the hillsides.
- There is a small area in the retirement village which cannot drain towards the southeast to the infiltration pond. Runoff from this area is to be collected in a detention tank and then discharged into the Outlet Road table drain using the existing Sub-catchment B2 flow path.
- Lastly, the two areas of the retirement village furthest to the east are to drain into the Stage 15 stormwater network, which has been designed and sized to accept runoff flows from the Northbrook area. Stormwater from the Stage 15 development area also drains into the infiltration pond.

Refer to Figure 4.1 below which shows the local flow paths in and around the Northbrook Retirement Village.

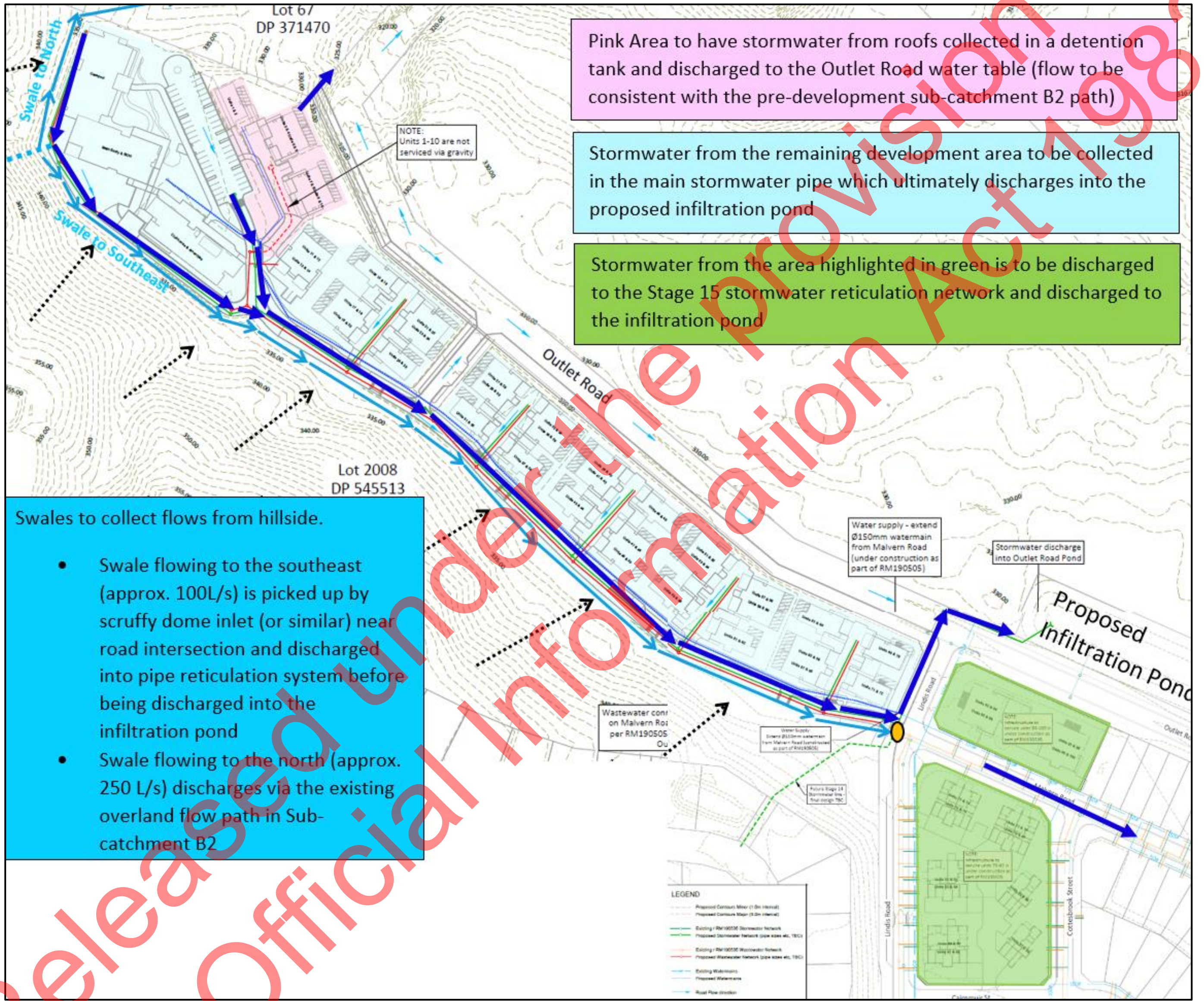


Figure 4.1: Local Northbrook Retirement Village Stormwater Flow Paths

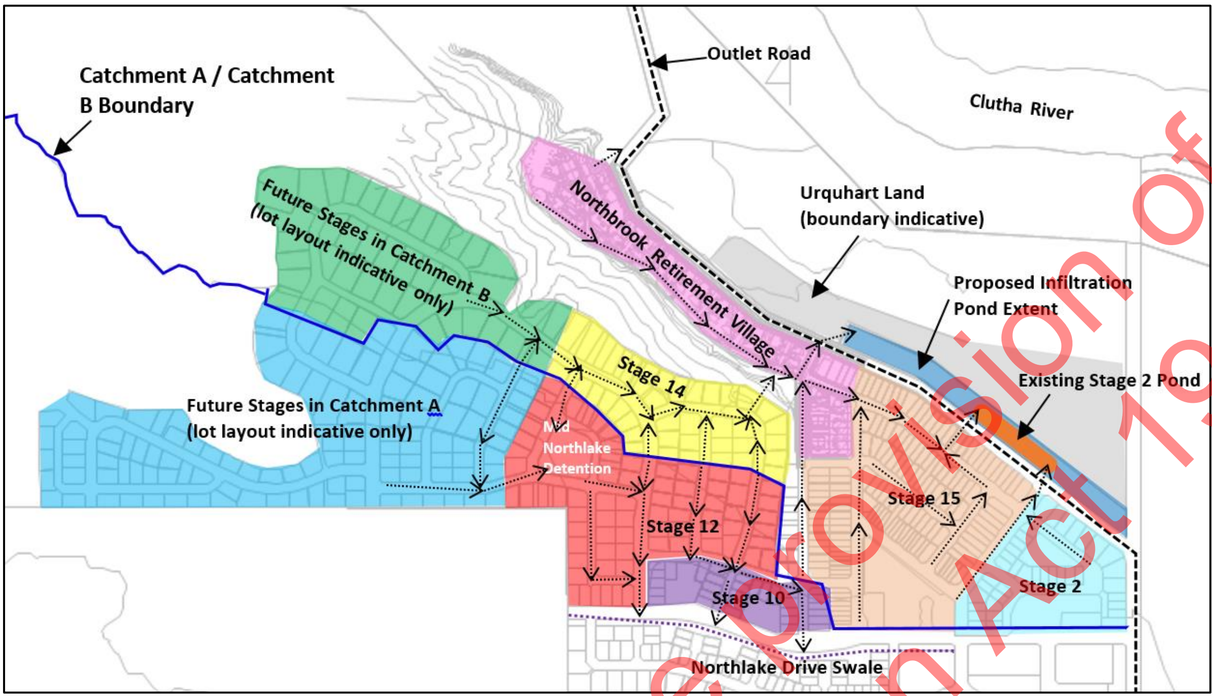


Figure 4.2: Stormwater Flow Paths and Pond Extent

Additionally, Figure 4.2 shows the development of the infiltration pond design. A summary of the development of the infiltration pond design is set out below:

- A small infiltration pond was originally developed as a stormwater disposal system for Stage 2 (fully constructed).
- The small infiltration pond was also assessed to be large enough to accept runoff flows from Stages 15A and 15B (engineering approval granted).
- Subsequent development stages in Catchment B (remainder of Stage 15 and Stage 14) required increased capacity of the pond (described under a previous subdivision consent process).
- Additionally, inflows from the stormwater runoff from future stages upstream of Stage 14 and the new retirement village needed to be assessed against the pond capacity. As a result, the pond size was increased from the original small infiltration pond developed for Stage 2. The revised larger infiltration pond has been assessed to have enough capacity to accept stormwater flows from the future urban area in Sub-catchment B2 and all of the development and natural / unbuilt land areas in Sub-catchment B1.

Note that the runoff inflow estimation for the infiltration pond includes an allowance for the neighbouring, Urquhart land (legally described as Lot 68 DP371470) to be developed and have its stormwater managed as part of the proposed infiltration pond.

More specifically, the proposed stormwater infiltration pond system is designed to receive stormwater flows from the development areas in the wider Catchment B area, primarily consisting of Sub-catchment B1 (Stages 2, 14, and 15 and the retirement village), as well as the future development area upstream of Stage 14 and a small portion of the retirement village located in Sub-catchment B2. These development areas in Sub-catchment B2 are to be diverted into the infiltration area in Sub-catchment B1. Catchment diversions for the area upstream of Stage 14 are to be dealt with as part of the consenting process for these future stages. The undeveloped areas in Sub-catchment B2 would continue to flow to the Clutha River via established overland flow paths.

4.2 Pond Capacity Summary

The proposed pond would be approximately 440m long, nominally 6m wide at the base and approximately 2.5m deep. The design would include a forebay for each stormwater inlet (three in total), similar to the existing Stage 2 pond. A driveway access through the middle of the pond has been allowed for to maintain the existing access to the Urquhart land. A culvert under the driveway access would be provided to allow for flow distribution throughout the pond.

A pond capacity assessment was completed to:

- Estimate the magnitude of the stormwater runoff inflows from the fully developed area to the infiltration pond;
- Determine overland flow patterns for the pre- and post-development scenarios, and
- Understand the relative rate of development runoff inflow versus the infiltration rate into the underlying outwash gravels versus the rate of filling of the above ground storage available in the pond.

Stormwater runoff inflows into the pond were estimated using the hydrological and hydraulic modelling software Infoworks ICM. For this preliminary assessment, the runoff for the lots and roads was estimated using the SCS routing methodology and infiltration values for pervious and impervious areas. The design rainfall hydrographs include allowance for climate change (HIRDS Version 4 – RCP8.5 (2090-2100)).

Subsequently, a dynamic surface runoff inflow versus infiltration to ground model was created to assess the available surface (above ground) volume and available outwash gravel volume. An overview of the model is included in Appendix 2. The model and effects assessment will be developed further as part of the detailed design.

Table 4.1 below shows the results of the preliminary pond capacity assessment and model results. Results are shown for the 100-year ARI storm event for durations ranging from 0.5hrs to 48hrs.

Table 4.1: Stormwater Management Catchment B – Infiltration Pond System Capacity – Preliminary Results

Storm Event	Peak Inflow from Catchment (m3/s)	Total Volume of Inflow (m3)	Total Infiltration to Outwash Gravels (m3)	Estimated Peak Water Level in Pond (m)	Freeboard from Pond Max WL to Top of Pond Bank – RL 328.0m (m)
100yr, 0.5hr	4.34	4,020	1,000	326.3	1.7
100yr, 1hr	4.51	7,160	2,224	326.7	1.3
100yr, 2hr	4.53	12,390	2,600	327.2	0.8
100yr, 6hr	2.92	23,460	7,800	327.8	0.2
100yr, 12hr	1.82	29,610	14,864	327.9	0.1
100yr, 24hr	1.05	32,300	14,860	327.9	0.1
100yr, 48hr	0.42	32,320	16,850	327.9	0.1

The shorter duration storms are estimated to deliver the peak post-development runoff flow into the pond area. The shorter duration rainfall events deliver smaller total volumes, albeit at higher peak flow rates. In this case, the flow into the pond is at a faster rate than what can drain into the underlying gravels, which causes a temporary filling of the pond, though at a volume less than the critical (longer duration) storm event. In contrast, the longer duration storms discharge a greater volume into the pond at a lesser peak flow.

The results indicate that the peak water elevation in the pond occurs in the 12 to 48hr duration storm events and has approximately 0.1m freeboard from the top of the pond bank. It is proposed to increase the pond bank adjacent to the Urquhart land to allow for 0.5m freeboard above the 100-year ARI flood level for future development areas in the Urquhart land. Residential development areas along Outlet Road in Northlake land are situated above the pond bank (freeboard to be confirmed as part of detailed design).

In the event of succession of large rainfall events, the infiltration pond would likely not have time to fully drain between rainstorms. For this purpose, the 100-year 48hr storm event has been used to provide a check on pond performance in large / successive rainfall events. The observations are as follows:

- The total rainfall for a 100-year 48hr rainfall event is 178mm (including inclusion of RCP8.5 (2090 – 2100) climate change factor).
- The monthly rainfall over the past 20years has been compared with the 48hour duration rainfall total. Adjusting for climate change, the maximum monthly rainfall depth is estimated to only be 172mm.
- The monthly rainfall total would typically be successive rainfall events and therefore the gaps in the rainfall events would allow the pond to drain to ground somewhat between events, thus restoring the surface storage volume for successive events.
- From Table 4.1 above, the infiltration pond can contain the 48hr event with approximately 0.1m freeboard and therefore would contain the successive and long duration rainfall events.

5.0 Effects Assessment

In the pre-development situation, flows from Catchment B drain to a series of ponding areas and / or overland flow paths (see Section 2.1.2). The Sub-catchment B1 portion of Catchment B naturally drains to soakage ponds along Outlet Road, and ultimately discharges as subsurface flow to the Clutha River. The Sub-catchment B2 portion of Catchment B drains via a shallow surface flow to a small ponding area which then drains via Outlet Road and other well-defined surface flow paths to the Clutha River.

The majority of the Northbrook Retirement Village is contained within Sub-catchment B1. The stormwater management concept to deal to the remainder of the Catchment B developable area involves diverting flood flows from Sub-catchment B2 into the infiltration pond in Sub-catchment B1 (particularly the future stages upstream of Stage 14 and a small area of the retirement village). Consent for the diversion of flows from Sub-catchmentB2 to B1 for the future stages upstream of Stage 14 would be completed at a later date. However, both Sub-catchments B1 and B2 ultimately drain to the Clutha River – either by surface flow (B2) or subsurface flow (B1).

Directing all stormwater from the development area in Catchment B to a single infiltration pond would reduce the flows entering into the incised surface flow gully in Sub-catchmentB2. The incised valley is an ephemeral watercourse and therefore a reduction in the volume of stormwater runoff would improve stability of the incised flow path channel. The addition of the developable area upstream of Stage 14 and a small portion of the retirement village into the disposal system for Sub-catchment B1 would ultimately improve the situation in Sub-catchment B2, while not causing an adverse effect in Sub-catchment B1. The method of utilising the infiltration pond as a means of stormwater disposal to ground replicates the drainage method observed in the pre-development condition.

6.0 Conclusions

Stormwater management for the Northbrook Retirement Village (Wanaka) is contained entirely within Catchment B. The stormwater management concept builds on the stormwater management design previously developed for Catchment B as part of Stages 2 and 15.

Stormwater runoff from the retirement village is to be collected and discharged to the infiltration pond by a pipe network system. A small area of the retirement village is not able to drain towards the infiltration pond and would be collected and discharged to the north along the Outlet Road table drain.

The infiltration pond has been sized to cater to existing development, the retirement village, and future development areas in Catchment B. Consents for diversion of flows from Sub-catchment B2 to B1 would be sought as part of the future development stages. When looking at the wider Catchment B stormwater management approach, utilisation of a single disposal pond in Sub-catchment B1 reduces the volume of surface flow entering the incised surface flow path to the Clutha River in Sub-catchment B2, therefore, helping to reduce the natural erosion occurring in this channel for the daily / frequent events.

Appendix 1

Geosolve Report "Geotechnical Report for Stormwater Disposal" – Revision 2 dated 28 May 2019

GEOSOLVE

GEOTECHNICAL

WATER RESOURCES

PAVEMENTS

Geotechnical Report for Stormwater Disposal

Northlake,

Wanaka

Report prepared for:

Northlake Investments Limited

Report prepared by:

GeoSolve Limited

Distribution:

Northlake Investments Limited

GeoSolve Limited (File)

May 2019

GeoSolve Ref: 170027.01

Revision	Issue Date	Purpose	Author	Reviewed
1	18/04/19	Draft for discussion with project team	MDP	EGM/FAW
2	28/05/19	Finalised Report	MDP	EGM/FAW

GEOTECHNICAL WATER RESOURCES PAVEMENTS

Table of Contents

1 Introduction

1.1 General

This report details the results of a stormwater disposal investigation by GeoSolve Limited for future stages of the Northlake development, at a site on Outlet Rd, Wanaka.

The work described in this report has been completed in accordance with the terms and conditions outlined in GeoSolve proposals reference number 170027.01 dated 28 March 2019. Previous work was undertaken as per GeoSolve proposal references 170027 and 170372.

The opinions and conclusions presented in this report are based on the following sources of information:

- Site inspections by a senior engineering geologist;
- Test pitting and geological mapping;
- Standpipe field permeability testing;
- Soak pit testing;
- A review of historic information currently held on the GeoSolve database for other sites in the local area;
- A review of the Queenstown Lakes District Council (QLDC) Hazard Register Maps (2002), and;
- A review of the published geological map, 'Institute of Geological & Nuclear Sciences Ltd, Geology of the Wakatipu, 1:25,0000 Geological Map 18'.

2 Geosolve Scope

The scope of work as outlined in the proposals includes field mapping, excavation and logging of test pits, infiltration testing within those test pits, followed by reporting to provide data for the design of a stormwater infiltration system.

Additional test pits and soakage testing was undertaken in April and May 2019 to further define the extents of the identified outwash channel and to undertake longer duration soakage tests corresponding to critical design storm durations.

3 Site Topography

Two oval depressions approximately 50 m and 100 m long and 2 m deep lie in an otherwise sub-horizontal outwash channel immediately to the northeast of Outlet Rd. These depressions and the extension of the channel to the east have been identified as potential infiltration areas for stormwater. The channel is surrounded by hummocky terrain.

4 Geotechnical Investigations

GeoSolve has conducted four phases of geotechnical investigations for the purposes of determining a geological model of the site and assessing the feasibility of stormwater disposal. These were conducted on:

- 19-20 January 2017;
- 1-3 February 2017;
- 8 June 2017; and,
- 5-8 April and 2 May 2019.

In total, 27 test pits extended to a maximum of 7 m depth, three open pit soak pit tests within TPs 4, 7 and 21 and one standpipe permeability test (HT21) within TP5 were completed within the previous stages of investigations.

- This updated report also includes the findings from the most recent phase of investigations (5-8 April and 2 May) comprising:
- 12 additional test pits extending to a maximum depth of 4.5 m, and;
- Five open pit soakage tests (TP 28, 30, 33, 38 and 39).

The purpose of the recent investigations was to identify the vertical and lateral extent and soakage rates of the outwash channel to the west and east, either side of the areas previously investigated.

Test pit and soak pit locations and logs are contained in Appendices A and B respectively.

5 Subsurface Conditions

5.1 Geological Setting

The site is located in the Wanaka Basin, a feature formed predominantly by glacial advances. The schist bedrock within the basin has been extensively scoured by ice and lies at considerable depth below the site.

During the Hawea-Mt Iron Glacial Advance (18-23,000 years before present), the Wanaka glacier terminated in the vicinity of the site, depositing hummocky glacial moraine. With subsequent glacial retreat, an outwash channel formed following the line of the Outlet Rd where the current site is located (see Site Plan, Appendix A). The channel is about 200 m wide in the middle of the site area but narrows to 80 m at the upstream (western) end.

The two oval depressions within the outwash channel are considered to be "kettle holes" due to the melting of glacial ice buried beneath the channel. They contain a thin deposit of silty pond sediments.

Hummocky moraine composed of glacial till lies either side (northeast and southwest) of the channel, and glacial till is inferred to underlie the outwash within a few meters from the ground surface

5.2 Stratigraphy

The interpreted stratigraphic model of the site is shown on Cross-sections AA'- JJ', Appendix A.

The stratigraphic sequence within the outwash channel generally consists of the following:

- 0.2-0.7 m of **topsoil**, overlying;
- 0.2-0.9 m of **loess**, overlying;
- 0.2-6.4+m (basal contact not confirmed) of **outwash gravel** containing generally subordinate lenses of **outwash sand**;
- In test pits towards the sides of the outwash channel, **glacial till** was found beneath the outwash, but near the channel axis glacial till was not penetrated at the maximum capable depth of the excavator.

The depressions within outwash channel contained 0.7-1.7 m of **glacial pond sediment** overlying the outwash gravel.

Test pits on the outwash channel sides found glacial till underlying topsoil, loess and colluvium.

The soil types were described as follows:

Topsoil comprising organic SILT was observed at the surface of each test pit to depths of between 0.2-0.7 m.

Loess underlies the topsoil and comprises firm to stiff/loose to medium dense, sandy SILT to SILT and loose silty SAND to SAND with some silt.

Glacial pond sediment comprising firm to very stiff SILT was observed in test pits 2, 3 and 7 located in depressions in the outwash channel.

Outwash gravel comprises medium dense, silty sandy GRAVEL, sandy GRAVEL and GRAVEL with varying amounts of cobbles and boulders.

Within the outwash gravels were lenses/layers of **outwash sand** comprising medium dense, gravelly SAND and SAND. The proportion of sand within the outwash channel was significantly higher towards the east within the completed test pits. In test pit 5, 10, 11, 14, 19, 20 and 22 a layer of **outwash silt** was observed.

Glacial till comprises stiff to very stiff, gravelly sandy SILT and sandy SILT to medium dense, silty SAND with some to minor gravel, silty GRAVEL and gravelly silty SAND.

Full descriptions of the observed subsurface stratigraphy at the site is provided in the test pit logs in Appendix B.

5.3 Groundwater

The permanent groundwater table was not encountered during test pitting, although minor seepages were observed from perched water on glacial till and silt horizons. The regional groundwater table is inferred to lie at considerable depth below the base of the outwash channel, potentially coincident with the Clutha River. The closest borehole (reference RBH1, Figure 1, Appendix A) on the same terrace level was dry to 10 m below ground level.

6 Stormwater Disposal

6.1 Suitability of soil types

The geological investigations have identified the glacial outwash gravel channel running parallel to Outlet Road as the most suitable unit for stormwater disposal/infiltration.

The inferred subsurface geological model illustrated by Cross-sections AA' –JJ', presents a distinctive infilled channel of outwash gravel and sand, incised into glacial till. In the axis of the channel, the basal contact from glacial outwash gravel to glacial till has not been defined based on test pitting. The contact depth to glacial till has been inferred to be close to the base of the test pits within design calculations, which is likely to be conservative as it may be deeper depending on the level of incision. On the ground surface, the outwash channel can be traced eastwards as a broad feature for some hundreds of metres beyond the investigated area but becomes restricted in width to the west of the investigated site. The western extent of the outwash channel to the north of Outlet Road was able to be defined during additional investigations undertaken in April 2019 (see Cross Section A-A').

The oval depressions initially identified as potential infiltration areas contain bodies of silty glacial pond sediments that will need to be removed before the areas can be utilised as an infiltration basin.

Visual comparison of the outwash gravels with similar materials tested during Upper Clutha Valley hydro-electric investigations, suggests they have relatively high permeabilities. However, the permeability of the underlying glacial till soils would be expected to be low, based on soakage testing at previous Wanaka subdivisions, and is likely to be a limiting factor for large infiltration volumes. Figure 1 presents a visual representation of suitability for soakage based on the test pits.

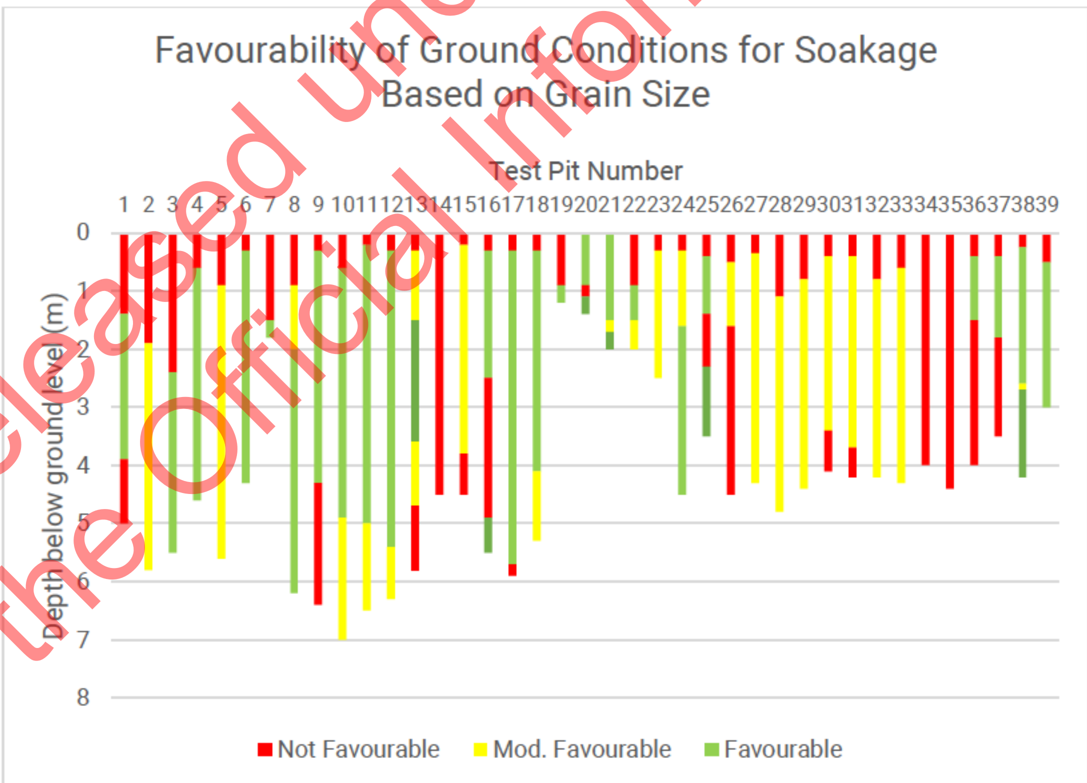


Figure 1. Suitability of soakage disposal based on soil type

Data presented in Figure 1 is also presented in tabular form in Appendix C.

6.2 Site testing

Soakage pit and standpipe field permeability testing was carried out within the outwash gravel at nine field locations (see Site Plan, Appendix A for test locations).

One of the tests was undertaken in the existing pond area (TP21); three downstream towards the southeast and one to the northwest.

Soakage testing was undertaken at the base of soak pits in TP4, TP7 and TP21. This was performed by introducing water from a 1,000L watercart until soakage within the pit reached equilibrium, i.e. inflow equalled soakage. The inflow was then ceased and the time it took for the water level to drop was then recorded. The standpipe field permeability test was undertaken using the HT21 methodology. Hydraulic conductivity was then obtained using published correlations (Van Hoorn, Glover, Phillip, HT21).

Additional soakage testing in April and May 2019 was undertaken at the base of soak pits in TP28, 30, 33, 38 and 39. This was performed by introducing water from an 8,000L watercart until soakage within the pit reached a set depth or the pit reached equilibrium. The inflow was then ceased and the time it took for the water level to drop was recorded.

The results were then analysed to determine indicative soakage and hydraulic conductivity rates, which are presented in Appendix C and summarised in Figure 2 and Table 1 below.

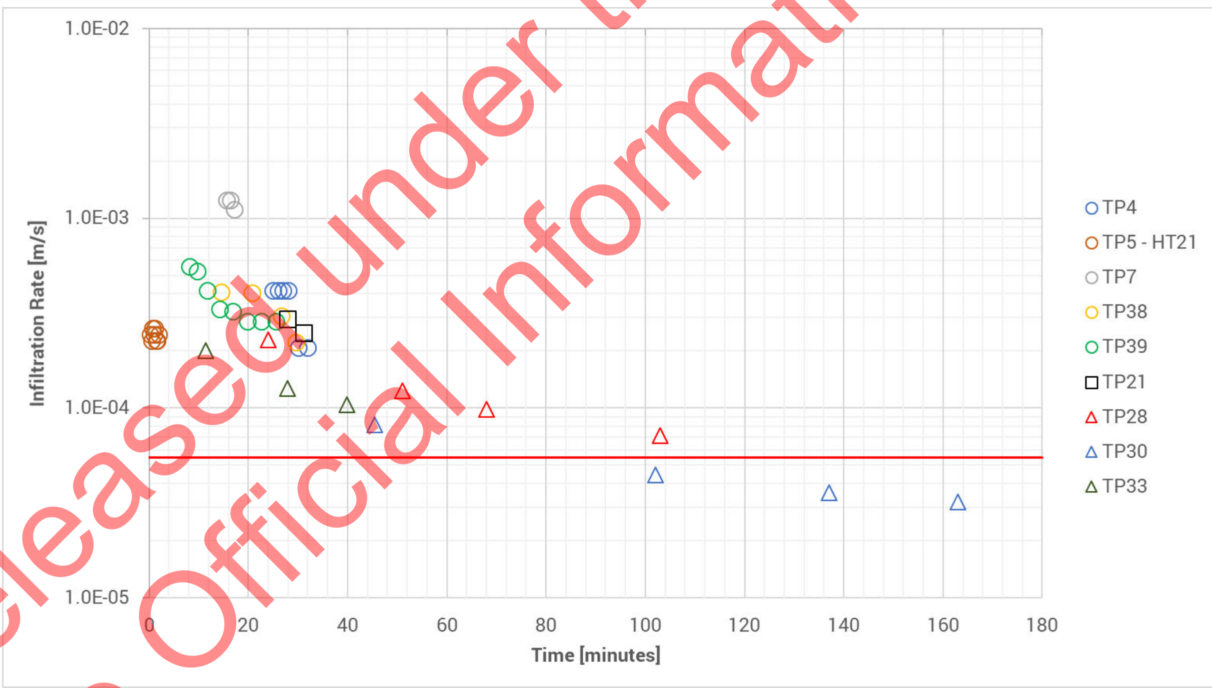


Figure 2. Measured vertical infiltration rate graphed against test duration. RED line = design value; Squares = within existing pond; Circles = the northwest; Triangles = southeast.

From Figure 1 it can be seen that some of the earlier testing may not have reached full saturation by the termination of the tests, despite being pre-saturated for 10-20 minutes. This could explain why subsequent tests to the southeast (e.g. TP28 and TP30), which were performed for much longer duration resulted in lower infiltration rates. Another and more likely explanation is that the soils toward the southeast become progressively finer, and the glacial till progressively shallower.

Table 1 Hydraulic Conductivity Values

Location		Test method	Infiltration rate*
Extension area to northwest	TP4	Open pit soakage test	2.1×10^{-4} m/s
	TP5	HT21 - Standpipe field permeability test	2.4×10^{-4} m/s
	TP7	Open pit soakage test	1.1×10^{-3} m/s
	TP38	Open pit soakage test	2.2×10^{-4} m/s
	TP39	Open pit soakage test	2.9×10^{-4} m/s
	Average, northwest extension area		**4.1×10^{-4} m/s**
Within existing pond	TP21	Open pit soakage test	2.5×10^{-4} m/s
Extension area to southeast	TP28	Open pit soakage test	7.1×10^{-5} m/s
	TP30	Open pit soakage test	3.2×10^{-5} m/s
	TP33	Open pit soakage test	1.0×10^{-4} m/s
	Average, southeast extension area		**6.8×10^{-5} m/s**
*High permeability values suggest the soil may not have reached full saturation by the termination of the test, despite at least 10-20 minutes of pre-saturation. Soak pits in TPs 28, 30, 33, 38 and 39 were run with an 8,000 L water cart as compared to the 1000 L water cart used for TPs 4, 7 and 21 to determine more accurate, longer-term soakage rates.			

6.3 Limitations of testing

Extensive permeability testing of outwash gravel was carried out for hydroelectric investigations in Upper Clutha Valley in the 1980s. This found typical bulk hydraulic conductivities (K) in outwash gravels, similar to those at Northlake, to be of the order of 4×10^{-4} m/s. This agrees well with the testing undertaken within the northwest extension area.

It is important to note that the subordinate sand and silt lenses and layers will have significantly lower permeability than the gravels, possibly of the order of 1×10^{-5} m/sec (sand) to 1×10^{-7} m/sec (silt) and will tend to lower the overall [bulk] hydraulic conductivity compared with that of the gravel component. The test pit logs indicate these layers constitute approximately 15% of the materials in the western area of outwash channel (TP1-22). The test pits completed as part of the additional investigations in April 2019 to the southeast of previous testing (TP26-33) observed regular interbedded sand, sandy gravel and gravelly sand layers. The sand layers are generally fine to medium grained, and it is estimated that the permeability will be typically of the order of 5×10^{-5} m/s. The sand was deposited in channel braids during flood events, the deposits are thus likely to be lensoidal and is being assessed as such in the design. The outwash silt is typically a smaller fraction and would have an estimated permeability in the order of 1×10^{-7} m/s. The horizontal and vertical heterogeneity of these units and their effect on infiltrating groundwater will be accounted for in the design.

Such effects appear to have influenced the testing further towards the southeast and east which resulted in reduced infiltration rates.

Estimation of a representative average hydraulic conductivity of the outwash channel soils is difficult, due to the geological complexity of the system. However, a provisional estimate of the order of 1×10^{-4} m/s is still considered reasonable for this unit, based on the site data and comparison with the known hydraulic conductivities of similar local outwash gravels.

6.4 Infiltration design

The most recent soakage testing completed over a longer duration within outwash deposits with a higher sand fraction to the southeast of the stormwater retention basin (typically described as interbedded SAND, sandy GRAVEL and gravelly SAND) in 2019 gave soakage rates that were somewhat lower than historic tests. These tests were completed over a total test time of between 53 and 158 mins compared to between 19 and 32 minutes in 2017 testing. Lower soakage rates to the southeast of the existing retention basin are likely attributed to the higher fraction of sand observed in test pits. Two additional soakage tests were completed in the area to the northwest of the existing soakage area to correlate results between 2017 and 2019 testing. Results indicate that infiltration/soakage rates provided in 2017 were a reasonable estimate for the area to the northwest of the existing infiltration area. The soakage rate determined from TP30 was seen to be lower than the rates for TP28 and TP33, presumably due to the underlying glacial till layer, of appreciably lower permeability, observed at 3.4 m bgl (soak test completed at 1.6 m bgl). Glacial till was not observed in TP28 and TP33 when the soak pit was excavated through following completion of the tests.

The underlying glacial till layer, having appreciably lower permeability, will be a limiting factor for infiltration design. In future design storms, this unit will facilitate a perched water table within the outwash gravels above, meaning that infiltration will be limited to the pore spaces within the outwash gravel.

We understand that Fluent Solutions have undertaken concept design of the future extensions (Stage 15 and Stage 2) and final stage (Full Catchment B and Urquhart Land) assuming an unfactored infiltration/permeability rate of $1x10^{-4}$ m/sec or $5x10^{-5}$ m/sec inclusive of a 0.5 reduction factor to account for potential loss of soakage performance over time. Further, we understand that Fluent have ignored all infiltration for between 1/3 to 1/4 of the pond to account for lower permeability results to the southeast.

A porosity value of 0.2 was applied to the outwash gravels. Further discussion on Fluent's design assumptions is provided in GeoSolve's design review memo.

Consideration of three-dimensional groundwater effects are recommended for large stormwater volumes disposed over large areas, which may be the case here. Further detailed modelling using finite-element or finite-difference methods could assist in this regard and should enable an optimised stormwater disposal system to be developed.

7 Conclusions and Recommendations

- The proposed infiltration area is within an outwash gravel channel containing sandy gravels, gravelly sands and sand lenses, and is inferred to be underlain by glacial till.
- Geological assessment and test pit Investigations has enabled estimation of the vertical and lateral extents of the outwash channel to the southeast and the boundary of the outwash channel to the northwest on the north side of Outlet Road.
- Two oval depressions in the surface of the outwash channel, originally identified as potential soakage areas, contain loess and silty glacial pond sediment up to 2.4 m thick that will need to be excavated and replaced with free draining gravel.
- The three 2017 soak pit tests in the outwash gravel to the northwest of the existing stormwater retention basin returned soakage rates of between 1×10^{-3} m/s to 2×10^{-4} m/s. Additionally, one standpipe field permeability test (HT21) in outwash gravel at TP5 gave a soil permeability value of 2.4×10^{-4} m/s.
- Three soakage tests were completed as part of the 2019 phase of testing within outwash deposits to the southeast of the existing stormwater disposal basin with a higher sand fraction as compared to what was observed to the northwest (typically described as interbedded SAND, sandy GRAVEL and gravelly SAND), these resulted in soil permeability values of between 1×10^{-4} m/s to 7×10^{-5} m/s.
- Two final soakage tests were completed to the northwest of the existing stormwater retention basin in May 2019 which gave soakage rates of between 2×10^{-4} m/s to 3×10^{-4} m/s. These correlate well with the results from 2017 testing.
- Based on the site geology, testing results and experience with similar outwash gravel deposits in the Upper Clutha Valley, the bulk permeability of the deposit is estimated to be of the order of 1×10^{-4} m/sec within the outwash gravel (centre and northwest of the pond) and 5×10^{-5} m/sec within the interbedded outwash sand and gravel.
- Sand and silt lenses within the outwash gravels will have significantly lower permeability than the sandy gravels and were observed more regularly to the southeast of the investigated area. It is recommended that design of the future extension accounts for the reduced permeability rates. Sand and silt lenses will have an effect on the overall global hydraulic properties and has been considered in the design.
- GeoSolve have reviewed Fluent Solutions' design assumptions for concept design of the proposed pond extension (covering "Stage 15 and Stage 2", and the "Final Stage") and consider their assumptions to be reasonable. Discussion on the key hydrogeological assumptions are contained within our design memo to Fluent Solutions.
- Further groundwater analysis will enable the sensitivity of the groundwater system to be assessed in three dimensions.

8 Applicability

This letter report has been prepared for the benefit of Northlake Investments Limited with respect to the particular brief given to us and it may not be relied upon in any other context or for any other purpose without our prior review and written agreement.

Site Investigation, reporting and analysis:

Graeme Halliday

....

Graeme Halliday | Mike Plunket

Senior Engineering Geologist | Geotechnical Engineer

Reviewed for GeoSolve Ltd by:

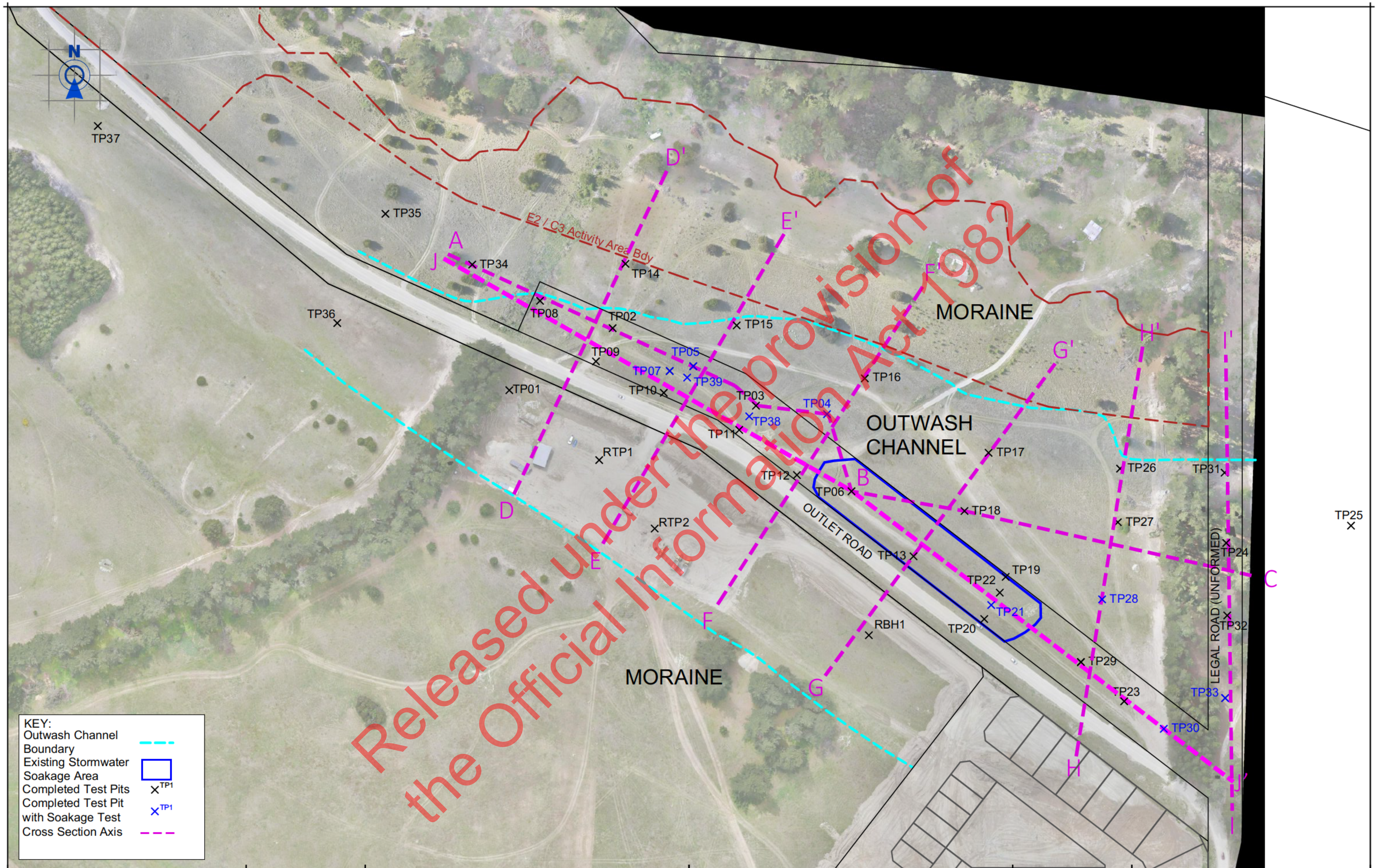
Eli Maynard

....

Eli Maynard | Fraser Wilson

Geotechnical/Water Resources Engineer | Senior Engineering Geologist

Appendix A: Site Plan & Cross-sections



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Client & Location:
NORTHLAKE
wanaka

Purpose & Drawing Title:
Test Pit Locations

Surveyed by:	DA	Original Size: A3	Scale: 1:2000 @ A3
Designed by:	PPG		
Drawn by:	DA		
Checked by:	MJB		DO NOT SCALE
Approved by:			

Job No:	Drawing No:	Sheet No:	Revision No:	Date Created:
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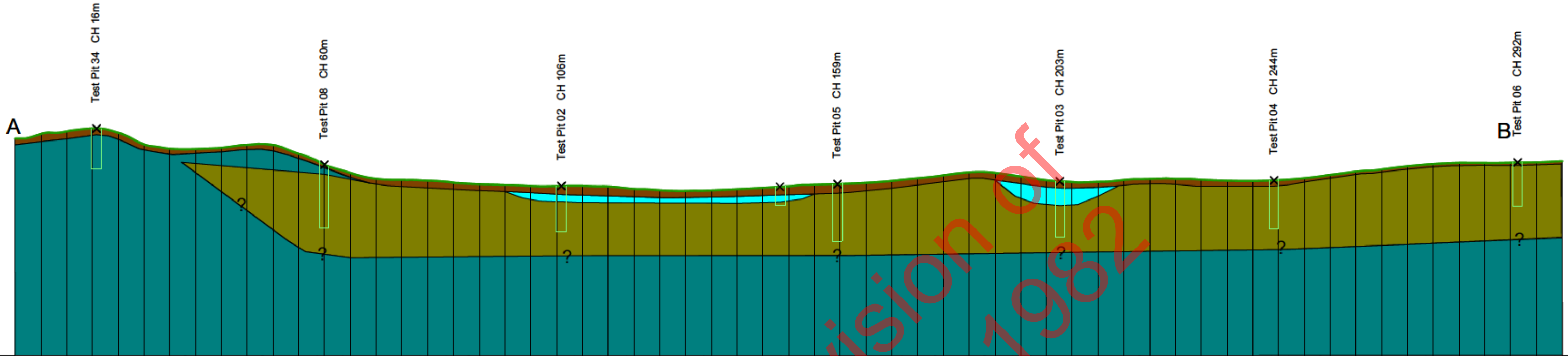

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65.00	326.68
70.00	326.12
75.00	326.01
80.00	325.93
85.00	325.73
90.00	325.59
95.00	325.52
100.00	325.41
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185.00	326.74
190.00	326.69
195.00	326.33
200.00	325.97
205.00	325.80
210.00	325.81
215.00	326.00
220.00	326.09
225.00	326.11
230.00	326.02
235.00	325.93
240.00	325.90
245.00	325.98
250.00	326.17
255.00	326.49
260.00	326.80
265.00	327.02
270.00	327.34
275.00	327.53
280.00	327.66
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290.00	327.68
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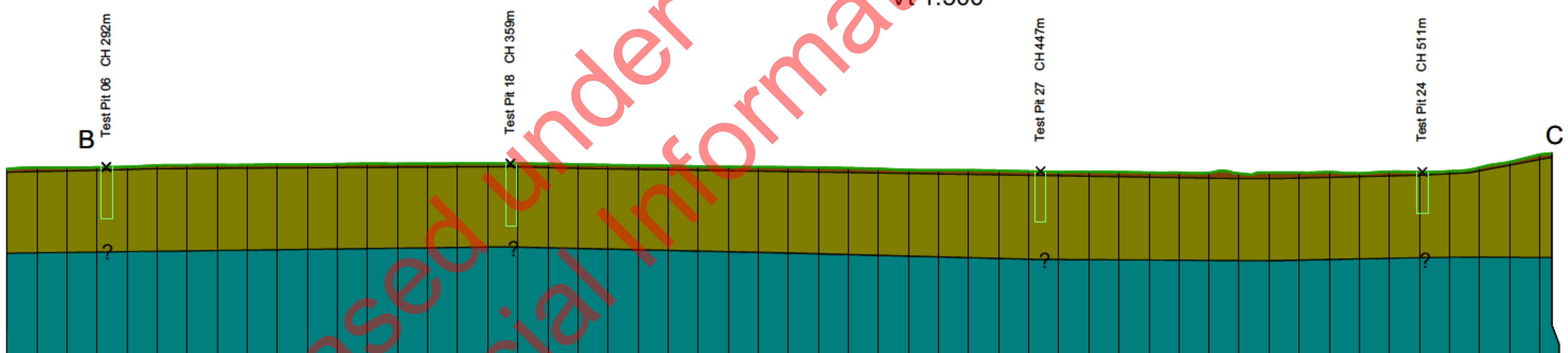
300.00	327.83

Natural Surface Cross Section A-C

Hz 1:1000

Vt 1:500



Datum RL 312.00

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315.00	327.86
320.00	327.92
325.00	327.92
330.00	327.94
335.00	327.97
340.00	327.96
345.00	327.99
350.00	328.00
355.00	327.97
360.00	327.99
365.00	327.95
370.00	327.91
375.00	327.86
380.00	327.81
385.00	327.80
390.00	327.75
395.00	327.71
400.00	327.70
405.00	327.67
410.00	327.65
415.00	327.59
420.00	327.54
425.00	327.45
430.00	327.42
435.00	327.42
440.00	327.38
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450.00	327.28
455.00	327.30
460.00	327.28
465.00	327.22
470.00	327.23
475.00	327.21
480.00	327.16
485.00	327.24
490.00	327.22
495.00	327.28
500.00	327.17
505.00	327.30
510.00	327.27
515.00	327.34
520.00	327.65
525.00	328.10
530.00	328.72
532.08	328.84

Natural Surface Cross Section A-C

Hz 1:1000

Vt 1:500

KEY:
- Topsoil, Loess and Colluvium
- Pond Sediment
- Outwash Sand and Gravel
- Glacial Till

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Purpose & Drawing Title:
Natural Surface Cross Section A-C

Surveyed by:	DA	Original Size: A3	Scale: SEE PLAN
Designed by:	PPG		
Drawn by:	DA		
Checked by:			DO NOT SCALE
Approved by:			
Job No: W5840	DWG No: 002	Sheet No: 101	Revision No: 0
			Date Created: 08/04/2019

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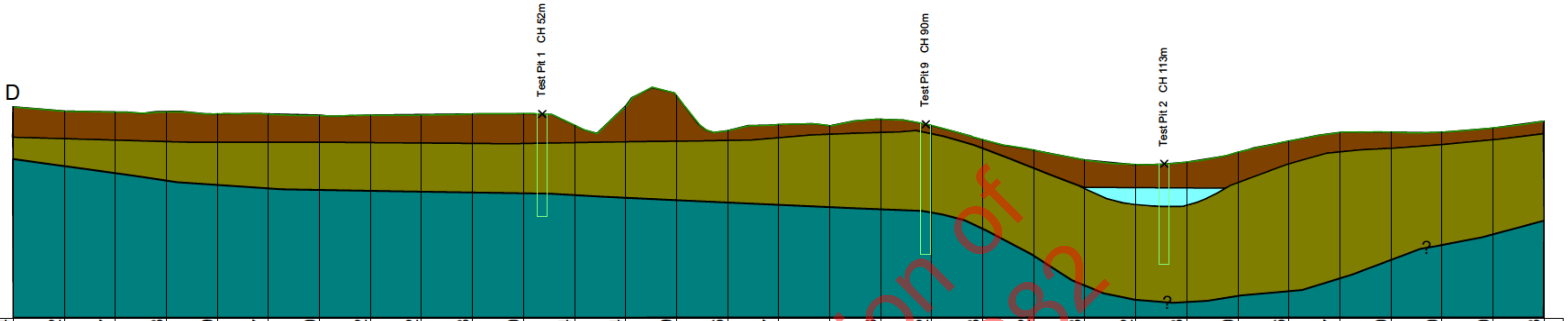

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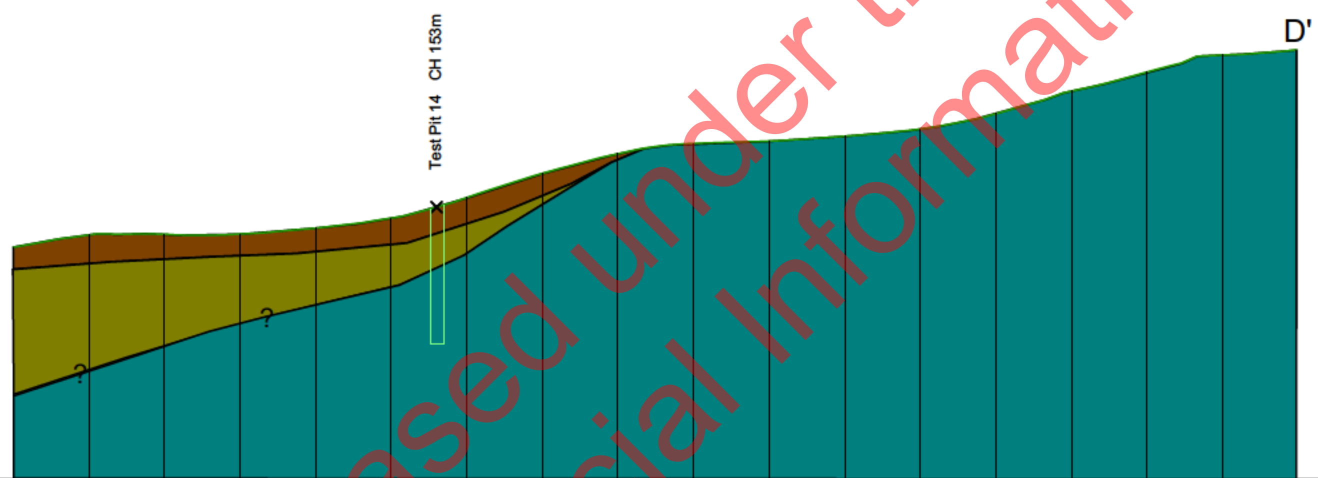
CHAINAGE	0.00	5.00	10.00	15.00	20.00	25.00	30.00	35.00	40.00	45.00	50.00	55.00	60.00	65.00	70.00	75.00	80.00	85.00	90.00	95.00	100.00	105.00	110.00	115.00	120.00	125.00	130.00	135.00	140.00	145.00	150.00

Natural Surface Cross Section D-D'

Hz 1:500

Vt 1:250



Datum RL 319.00

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CHAINAGE	125.00	130.00	135.00	140.00	145.00	150.00	155.00	160.00	165.00	170.00	175.00	180.00	185.00	190.00	195.00	200.00	205.00	209.87

Natural Surface Cross Section D-D'

Hz 1:500

Vt 1:250

KEY:
- Topsoil, Loess and Colluvium
- Pond Sediment
- Outwash Sand and Gravel
- Glacial Till

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Client & Location:

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Purpose & Drawing Title:

Natural Surface Cross Section D-D'

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Designed by:	PPG		
Drawn by:	DA		
Checked by:			
Approved by:			DO NOT SCALE

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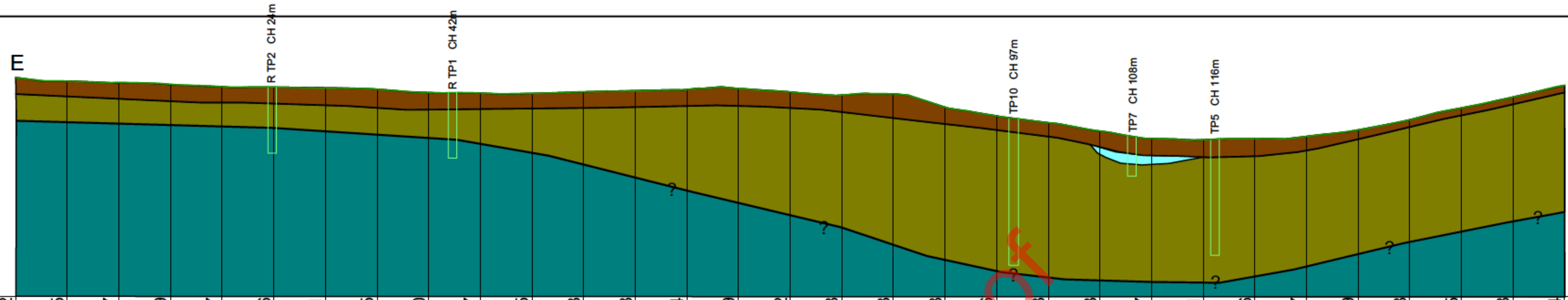

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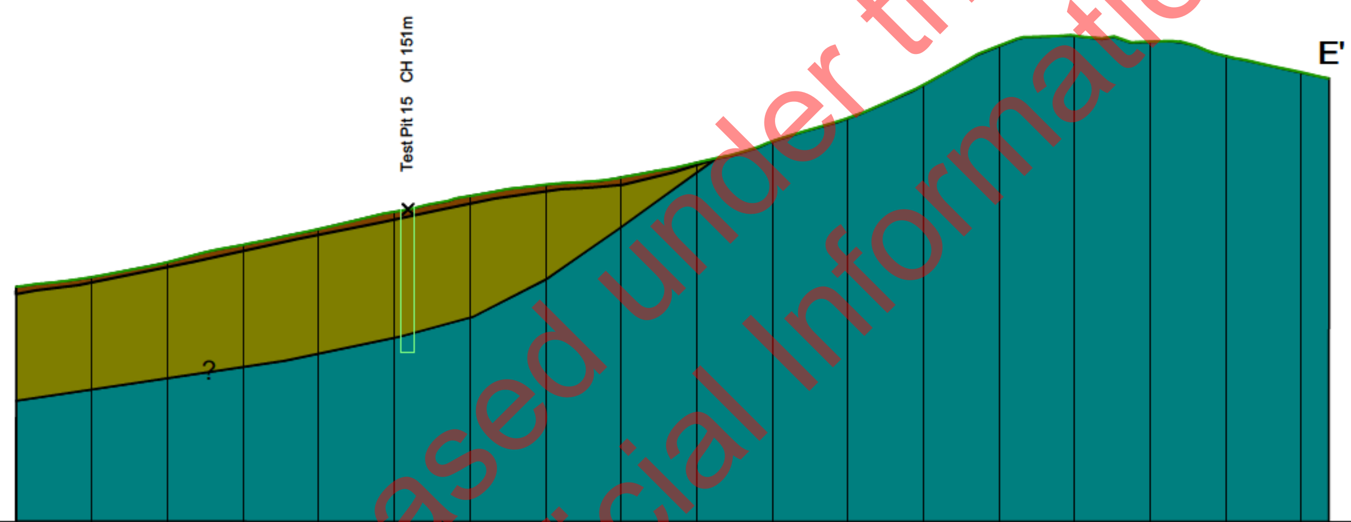
CHAINAGE	0.00	5.00	10.00	15.00	20.00	25.00	30.00	35.00	40.00	45.00	50.00	55.00	60.00	65.00	70.00	75.00	80.00	85.00	90.00	95.00	100.00	105.00	110.00	115.00	120.00	125.00	130.00	135.00	140.00	145.00	150.00

Natural Surface Cross Section E-E'

Hz 1:500

Vt 1:250



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CHAINAGE	125.00	130.00	135.00	140.00	145.00	150.00	155.00	160.00	165.00	170.00	175.00	180.00	185.00	190.00	195.00	200.00	205.00	210.00	211.84

Natural Surface Cross Section E-E'

Hz 1:500

Vt 1:250

KEY:
- Topsoil, Loess and Colluvium
- Pond Sediment
- Outwash Sand and Gravel
- Glacial Till

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Purpose & Drawing Title:

Natural Surface Cross Section E-E'

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Drawn by:	DA		
Checked by:			
Approved by:			DO NOT SCALE

Job No:	DWG No:	Sheet No:	Revision No:	Date Created:
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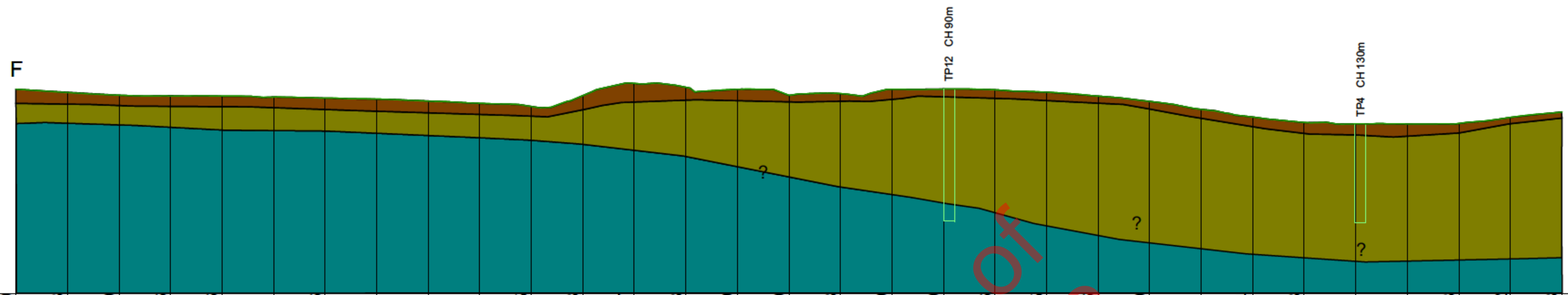

Datum RL 318.00

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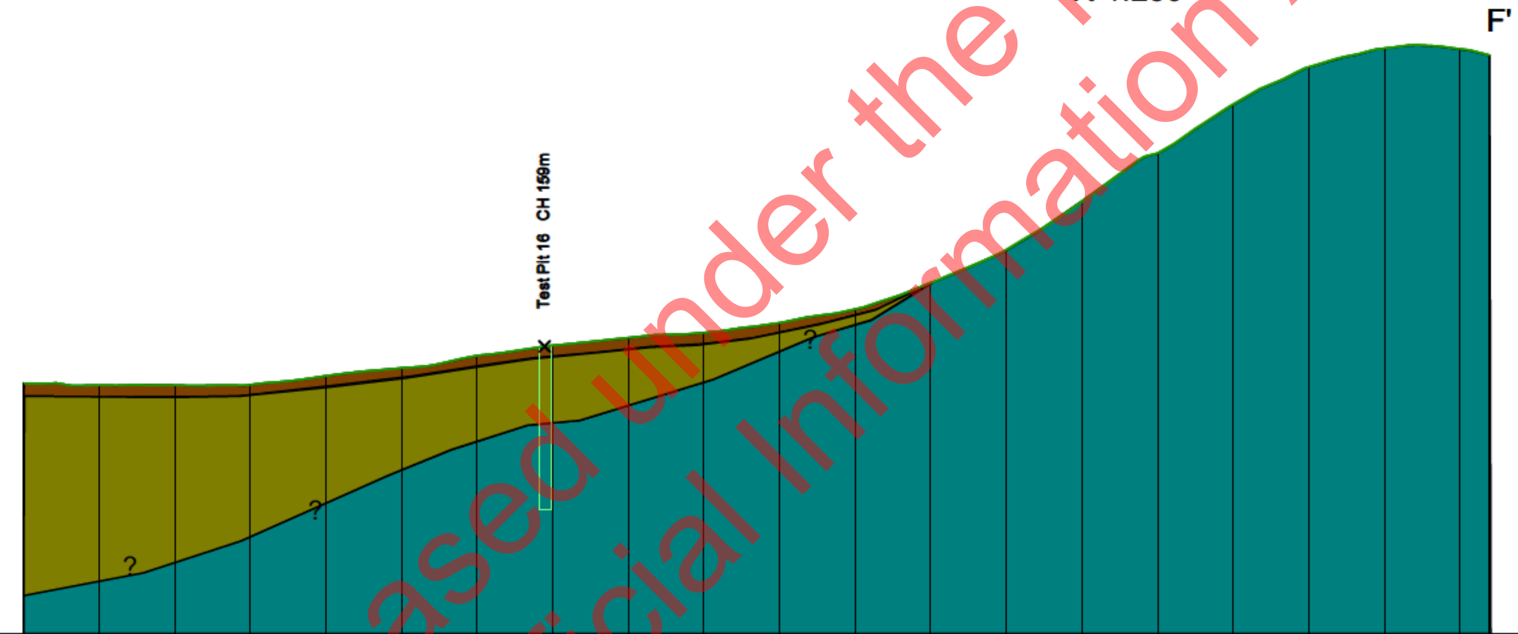
NATURAL SURFACE	327.68	327.89	327.90	327.86	327.75	327.56	327.30	326.91	326.54	326.28	326.21	326.21	326.23	326.52	326.78
CHAINAGE	80.00	85.00	90.00	95.00	100.00	105.00	110.00	115.00	120.00	125.00	130.00	135.00	140.00	145.00	150.00

Natural Surface Cross Section F-F'

Hz 1:500

Vt 1:250



Datum RL 318.00

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NATURAL SURFACE	328.28	328.73	329.61	330.70	332.30	333.89	335.51	336.74	337.36	337.34	337.13
CHAINAGE	175.00	180.00	185.00	190.00	195.00	200.00	205.00	210.00	215.00	220.00	221.95

Natural Surface Cross Section F-F'

Hz 1:500

Vt 1:250

KEY:
- Topsoil, Loess and Colluvium
- Pond Sediment
- Outwash Sand and Gravel
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Client & Location: Northlake Stages 1-3

Purpose & Drawing Title: Natural Surface Cross Section F-F'

Surveyed by:	DA	Original Size: A3	Scale: SEE PLAN
Designed by:	PPG		
Drawn by:	DA		
Checked by:			DO NOT SCALE
Approved by:			
Job No: W5840	DWG No: 002	Sheet No: 104	Revision No: 0
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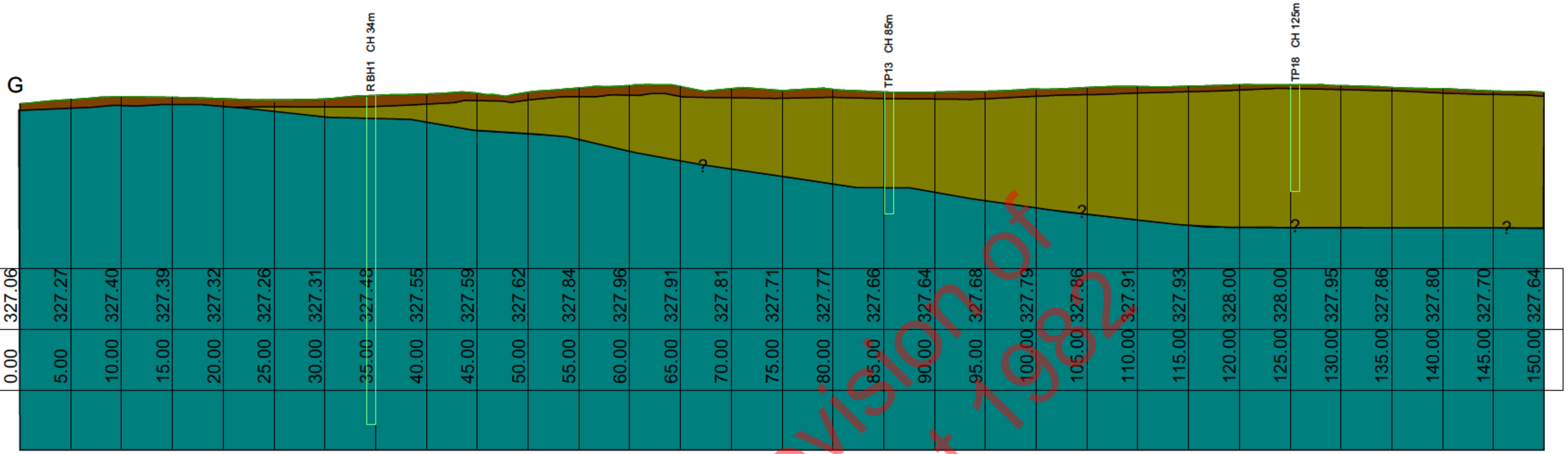

CHAINAGE	NATURAL SURFACE
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15.00	327.39
20.00	327.32
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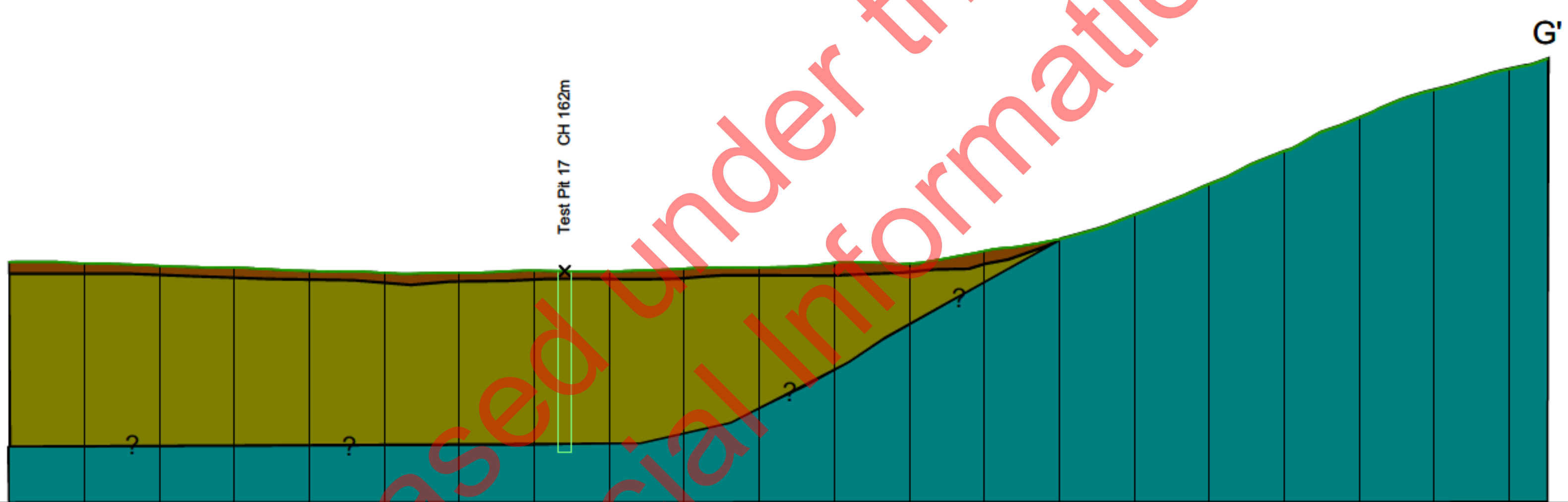
Natural Surface Cross Section G-G'

Hz 1:500

Vt 1:250



CHAINAGE	NATURAL SURFACE
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140.00	327.80
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150.00	327.64
155.00	327.64
160.00	327.71
165.00	327.68
170.00	327.77
175.00	327.82
180.00	327.97
185.00	327.94
190.00	328.36
195.00	328.75
200.00	329.56
205.00	330.58
210.00	331.68
215.00	332.80
220.00	333.72
225.00	334.41
227.57	334.76

Natural Surface Cross Section G-G'

Hz 1:500

Vt 1:250

KEY:
- Topsoil, Loess and Colluvium
- Pond Sediment
- Outwash Sand and Gravel
- Glacial Till

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Purpose & Drawing Title: Natural Surface Cross Section G-G'

Surveyed by:	DA	Original Size: A3	Scale: SEE PLAN
Designed by:	PPG		
Drawn by:	DA		
Checked by:			DO NOT SCALE
Approved by:			
Job No: W5840	DWG No: 002	Sheet No: 105	Revision No: 0
			Date Created: 08/04/2019

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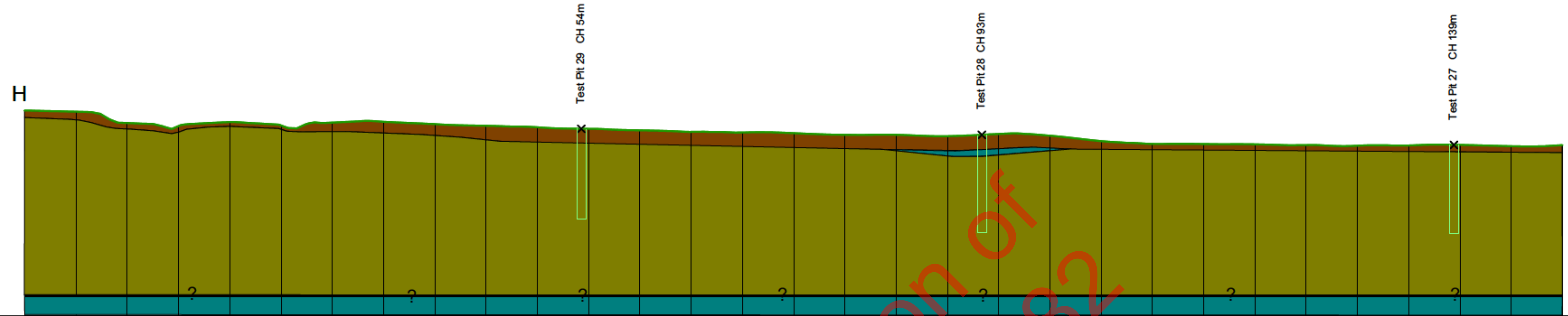
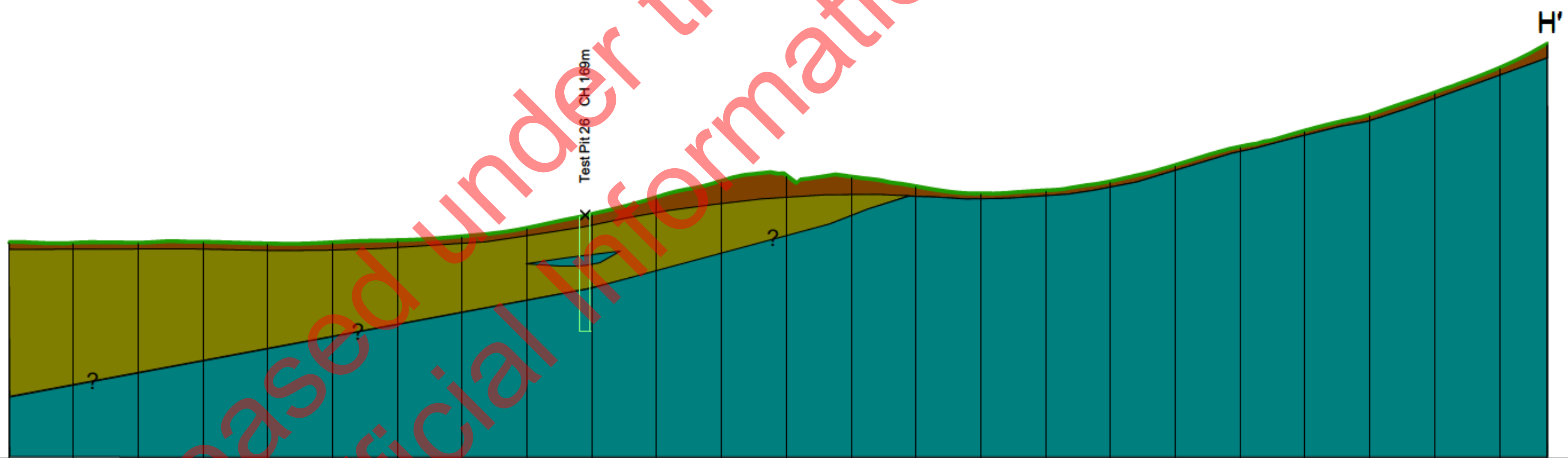


Datum RL 319.00

NATURAL SURFACE	328.99	328.93	328.38	328.23	328.42	328.26	328.40	328.44	328.33	328.25	328.17	328.10	328.02	327.95	327.92	327.89	327.81	327.80	327.74	327.85	327.76	327.50	327.36	327.35	327.34	327.30	327.27	327.28	327.31	327.25	327.30
CHAINAGE	0.00	5.00	10.00	15.00	20.00	25.00	30.00	35.00	40.00	45.00	50.00	55.00	60.00	65.00	70.00	75.00	80.00	85.00	90.00	95.00	100.00	105.00	110.00	115.00	120.00	125.00	130.00	135.00	140.00	145.00	150.00

Natural Surface Cross Section H-H'
Hz 1:500
Vt 1:250



Datum RL 319.00

NATURAL SURFACE	327.30	327.27	327.28	327.31	327.25	327.30	327.38	327.52	327.86	328.39	329.05	329.67	329.86	329.82	329.45	329.18	329.29	329.65	330.28	330.98	331.60	332.22	333.07	334.03	334.95
CHAINAGE	125.00	130.00	135.00	140.00	145.00	150.00	155.00	160.00	165.00	170.00	175.00	180.00	185.00	190.00	195.00	200.00	205.00	210.00	215.00	220.00	225.00	230.00	235.00	240.00	243.67

Natural Surface Cross Section H-H'
Hz 1:500
Vt 1:250

KEY:
Topsoil, Loess and Colluvium
Pond Sediment
Outwash Sand and Gravel
Glacial Till

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E wanaka@ppgroup.co.nz

Client & Location:
Northlake Stages 1-3

Purpose & Drawing Title:
Natural Surface Cross Section H-H'

Surveyed by:	DA
Designed by:	PPG
Drawn by:	DA
Checked by:	
Approved by:	
Original Size:	A3
Scale:	SEE PLAN
	DO NOT SCALE
Job No:	W5840
DWG No:	002
Sheet No:	106
Revision No:	0
Date Created:	08/04/2019

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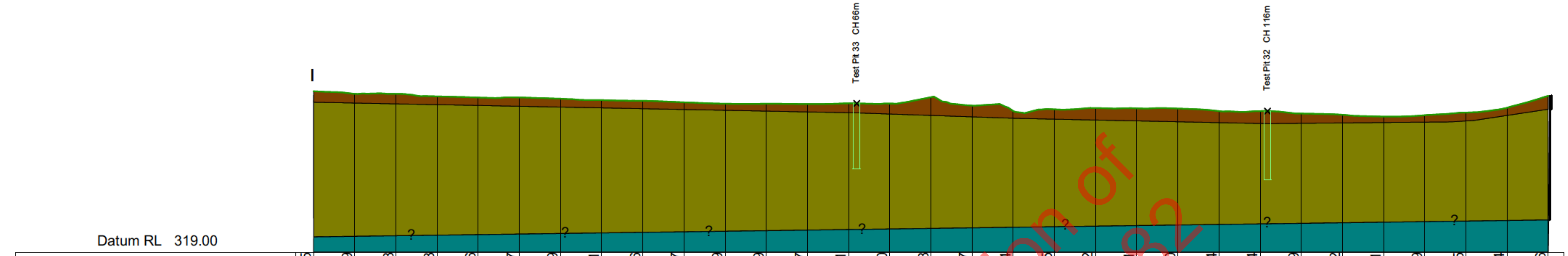
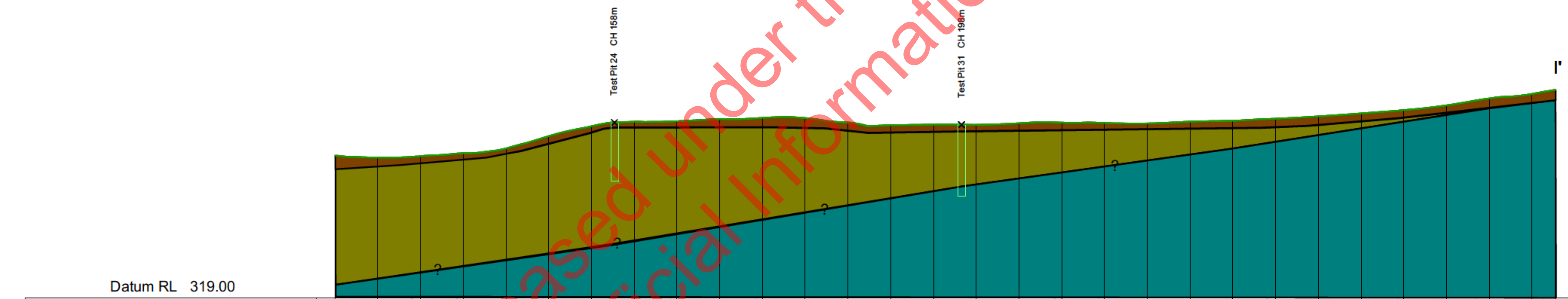


NATURAL SURFACE	328.75	328.59	328.58	328.43	328.36	328.37	328.29	328.21	328.16	328.07	327.99	327.99	327.97	328.01	328.00	328.38	327.87	327.54	327.65	327.72	327.71	327.70	327.54	327.54	327.39	327.32	327.21	327.29	327.45	327.74	328.46
CHAINAGE	0.00	5.00	10.00	15.00	20.00	25.00	30.00	35.00	40.00	45.00	50.00	55.00	60.00	65.00	70.00	75.00	80.00	85.00	90.00	95.00	100.00	105.00	110.00	115.00	120.00	125.00	130.00	135.00	140.00	145.00	150.00

Natural Surface Cross Section I-I'
Hz 1:500
Vt 1:250



NATURAL SURFACE	327.32	327.21	327.29	327.45	327.74	328.46	329.04	329.31	329.33	329.46	329.53	329.52	329.26	329.10	329.14	329.13	329.22	329.25	329.23	329.20	329.31	329.36	329.49	329.62	329.80	329.98	330.26	330.67	330.94	331.17
CHAINAGE	125.00	130.00	135.00	140.00	145.00	150.00	155.00	160.00	165.00	170.00	175.00	180.00	185.00	190.00	195.00	200.00	205.00	210.00	215.00	220.00	225.00	230.00	235.00	240.00	245.00	250.00	255.00	260.00	265.00	267.72

Natural Surface Cross Section I-I'
Hz 1:500
Vt 1:250

KEY:
Topsoil, Loess and Colluvium
Pond Sediment
Outwash Sand and Gravel
Glacial Till

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Client & Location:
Northlake Stages 1-3

Purpose & Drawing Title:
Natural Surface Cross Section I-I'

Surveyed by: DA	Original Size: A3	Scale: SEE PLAN	
Designed by: PPG			
Drawn by: DA			
Checked by:		DO NOT SCALE	
Approved by:			
Job No: W5840	DWG No: 002	Sheet No: 107	Revision No: 0
			Date Created: 08/04/2019

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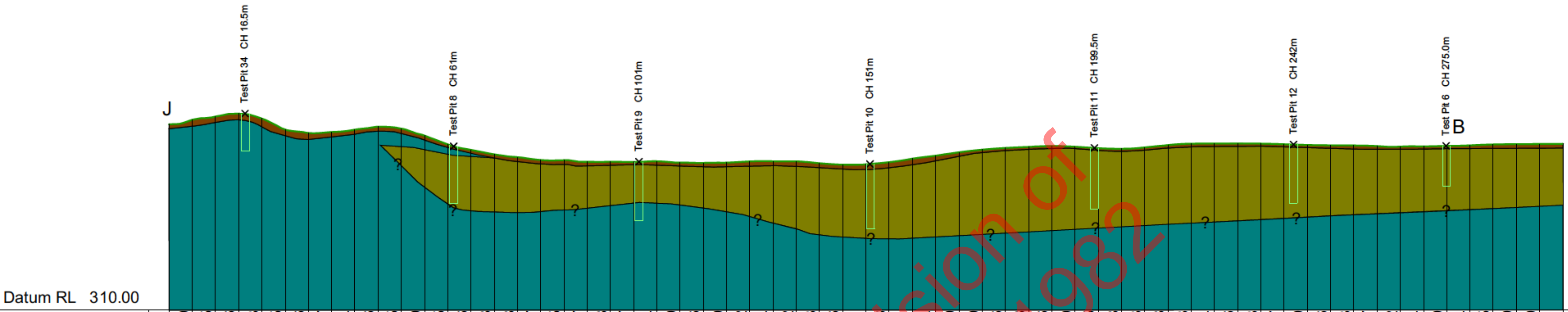
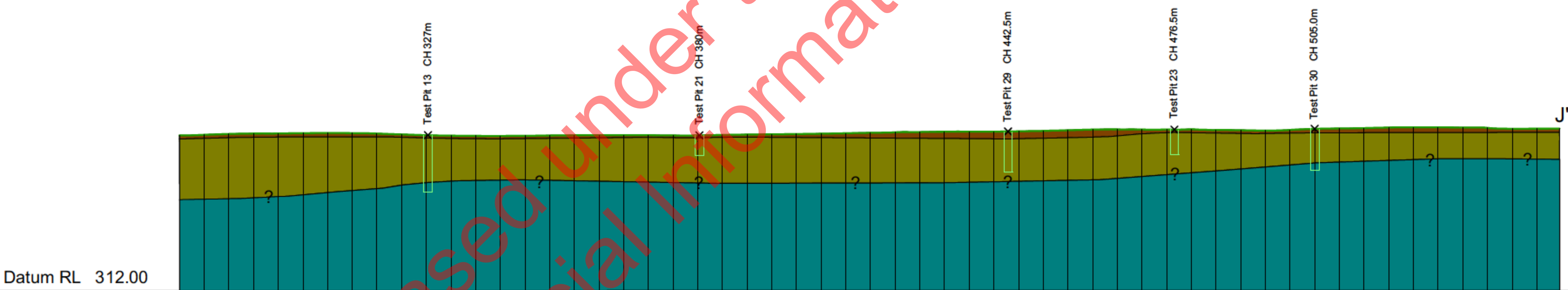


CHAINAGE	NATURAL SURFACE
0.00	330.01
5.00	330.50
10.00	330.85
15.00	331.16
20.00	330.63
25.00	329.45
30.00	329.06
35.00	329.17
40.00	329.44
45.00	329.76
50.00	329.55
55.00	328.79
60.00	327.85
65.00	327.26
70.00	326.78
75.00	326.48
80.00	326.17
85.00	326.15
90.00	325.97
95.00	325.98
100.00	325.97
105.00	326.04
110.00	325.89
115.00	325.86
120.00	325.89
125.00	326.02
130.00	326.04
135.00	326.02
140.00	325.83
145.00	325.66
150.00	325.71
155.00	325.93
160.00	326.31
165.00	326.64
170.00	326.99
175.00	327.29
180.00	327.46
185.00	327.58
190.00	327.66
195.00	327.60
200.00	327.45
205.00	327.38
210.00	327.53
215.00	327.78
220.00	327.93
225.00	327.94
230.00	327.96
235.00	327.93
240.00	327.87
245.00	327.79
250.00	327.76
255.00	327.73
260.00	327.67
265.00	327.62
270.00	327.64
275.00	327.69
280.00	327.74
285.00	327.85
290.00	327.89
295.00	327.89
300.00	327.91

Natural Surface Cross Section J-B-J'

Hz 1:1000

Vt 1:500



CHAINAGE	NATURAL SURFACE
275.00	327.69
280.00	327.74
285.00	327.85
290.00	327.89
295.00	327.89
300.00	327.91
305.00	327.94
310.00	327.93
315.00	327.89
320.00	327.79
325.00	327.70
330.00	327.66
335.00	327.65
340.00	327.64
345.00	327.66
350.00	327.69
355.00	327.70
360.00	327.72
365.00	327.73
370.00	327.71
375.00	327.68
380.00	327.69
385.00	327.74
390.00	327.77
395.00	327.80
400.00	327.84
405.00	327.87
410.00	327.91
415.00	327.96
420.00	328.01
425.00	328.03
430.00	328.05
435.00	328.07
440.00	328.08
445.00	328.11
450.00	328.15
455.00	328.21
460.00	328.29
465.00	328.30
470.00	328.29
475.00	328.29
480.00	328.30
485.00	328.24
490.00	328.22
495.00	328.18
500.00	328.25
505.00	328.35
510.00	328.40
515.00	328.44
520.00	328.49
525.00	328.52
530.00	328.51
535.00	328.50
540.00	328.45
545.00	328.36
550.00	328.37
554.62	328.38

Natural Surface Cross Section cross section J-B-J'

Hz 1:1000

Vt 1:500

KEY:
- Topsoil, Loess and Colluvium
- Pond Sediment
- Outwash Sand and Gravel
- Glacial Till

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Client & Location: Northlake Stages 1-3

Purpose & Drawing Title: Natural Surface Cross Section J-B-J'

Surveyed by:	DA	Original Size: A3	Scale: SEE PLAN
Designed by:	PPG		
Drawn by:	DA		
Checked by:			
Approved by:			DO NOT SCALE

Job No:	DWG No:	Sheet No:	Revision No:	Date Created:
W5840	002	108	0	23/04/2019

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