



Vine Street Manchester

Temporary Works Slope Stability Assessment
(November 2024)

Prepared for Earthwork Support Specialist (CE)
Ltd

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1 Introduction

Key GeoSolutions Ltd (KGS) has been commissioned by Earthwork Support Specialist (CE) Ltd to undertake a slope stability assessment for temporary works for installation of retaining sheet pile walls at Vine Street in Gorton in Manchester in order to ascertain the impact of the piling works on adjacent Network Rail slope and railway. Furthermore, the predicted Peak Particle Velocity (PPV) values of piling works based on historic data and applicable standards is assessed and provided.

1.1 Objectives

The objectives of the report are:

- To assess the effect of the piling works on the adjacent Network Rail slope and railway.
- To recommend mitigation and monitoring to verify assessment.
- To determine the risks associated with the proposed works.
- To provide predicted PPV values during temporary works.

1.2 Information

The following ground investigation and design information is available:

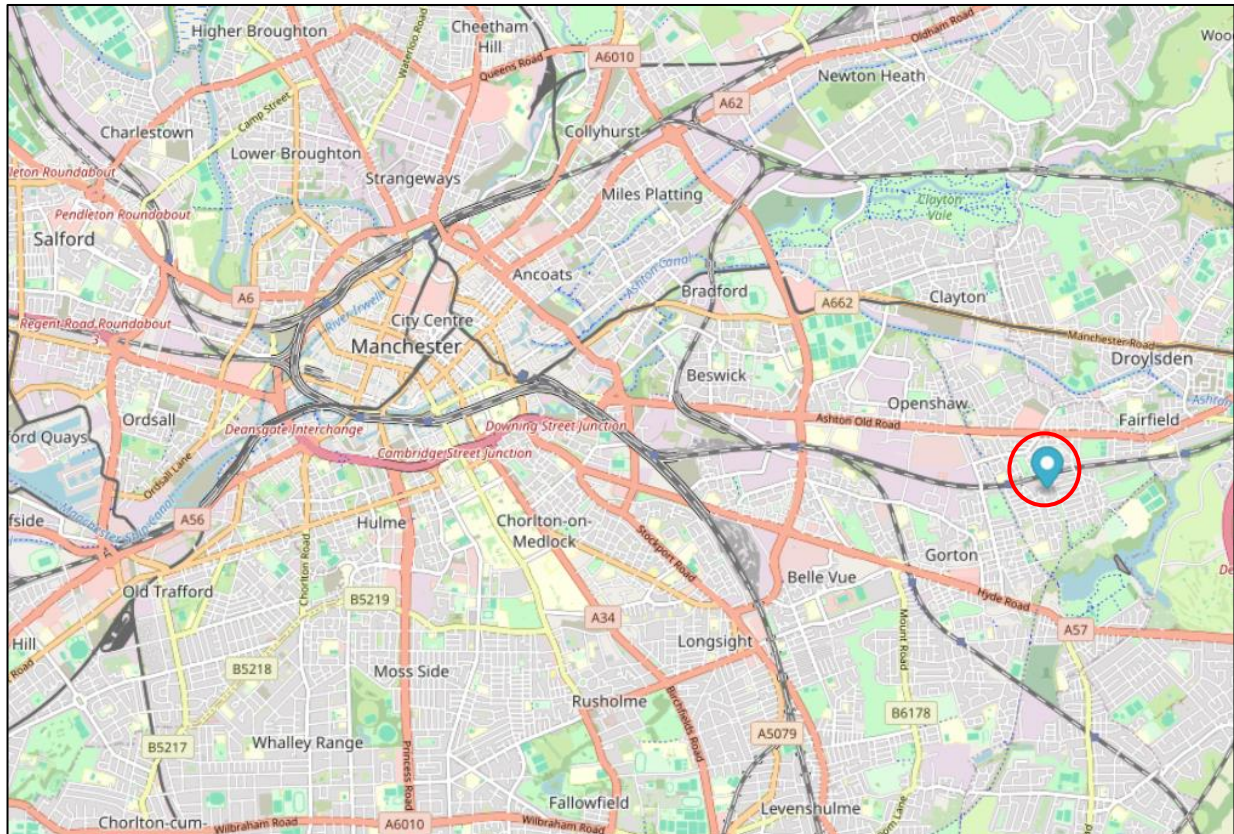
- Phase II Geoenvironmental Site Assessment – 14-944-R1-2 dated 11th January 2022
- Topographical Land Survey – S18-442 dated 29th May 2018
- Embankment Retaining Wall Proposal – 23042-001 dated 5th July 2023
- Sheet Pile Retaining Wall Design Calculations- Vine Street Manchester – 2664 dated 24th October 2023
- Sheet Piled Wall for Slope Stability Technical Note – E11417/PW01 TN01 dated 24th March 2022
- Vine Street Gorton Conventional Sheet Piling Method Statement dated 12th May 2023
- Proposed Finished Levels – VSG-RDG-XX-XX-DR-C-0001-P02 dated 14th April 2023
- Earthworks Cut and Fill Isopachytes – VSG-RDG-XX-XX-DR-C-0002-P04 dated 4th May 2023
- Proposed Levels Cross Sections - Sheet 1- VSG-RDG-XX-XX-DR-C-0004_P06 dated 5th May 2023
- Proposed Levels Cross Sections - Sheet 2- VSG-RDG-XX-XX-DR-C-0005_P06 dated 5th May 2023
- Proposed Levels Cross Sections - Sheet 3- VSG-RDG-XX-XX-DR-C-0006_P06 dated 5th May 2023
- Proposed Levels Cross Sections - Sheet 4- VSG-RDG-XX-XX-DR-C-0007_P05 dated 5th May 2023
- Proposed Levels Cross Sections - Sheet 5- VSG-RDG-XX-XX-DR-C-0008_P05 dated 5th May 2023

2 Site Overview

2.1 Site Location and Description

The site is located at the Gorton, Manchester and is located at National Grid Reference 389283mE, 396973mN and is shown on Figure 2.1-1. The closest postcode for the site is M18 8YB. The site is currently a fenced empty lot.

Figure 2.1-1: Site Location



3 Slope Stability

3.1 Slope Stability Assessment Objectives

The objectives of the slope stability assessment were to:

- Determine the stability of the Network Rail slope during temporary piling works.
- Assess whether the proposed piling works are appropriate
- Determine monitoring criteria and mitigation measures

3.2 Slope Stability Assessment Methodology

The following was undertaken as part of the design assessment:

1. Review the Ground Model and ground parameters based on data and reports provided.
2. Conduct slope stability analysis for Design Section 1 and Design Section 2 as presented in Sheet Pile Retaining Wall Design Calculations- Vine Street Manchester – 2664 dated 24th October 2023
3. Conduct slope stability analysis considering dynamic loading to account for piling works.
4. Define criteria for on-site monitoring of vibration.
5. Recommend possible mitigation measure at site during the works
6. Verify the slope behaviour and response during site monitoring.

3.3 Ground Model

British Geological Survey (BGS) maps indicated mapped superficial soil at the site is Till. This stratum is described as unsorted and unstratified drift, general over consolidated. It consists of a heterogenous mixture of clay, sand, gravel and boulders varying widely in size and shape. The mapped bedrock is the Manchester Marls Formation – Mudstone which are described as red marl (calcareous mudstone and siltstone) with thin beds of fossiliferous marine limestone and dolomite; locally green; sandy in places.

From the earliest map edition (1948), the site is shown to have been largely undeveloped and part of an open field, until a railway line is shown in the western portion from the 1890s. Cutting of the site appears to have taken place at several stages, associated with the development of the railway line and in the 1940s/50s, likely relating to adjacent infrastructure / developments. Unknown structures were present during the 1950s, likely relating to the railway, and remaining until c. 2000; Filling of the railway cutting is understood to have taken place following dismantling of the railway in c. 2000, which is also collaborated by available aerial imagery at this time.

Made Ground associated infilling of the railway cutting, is expected but not recorded in BGS records.

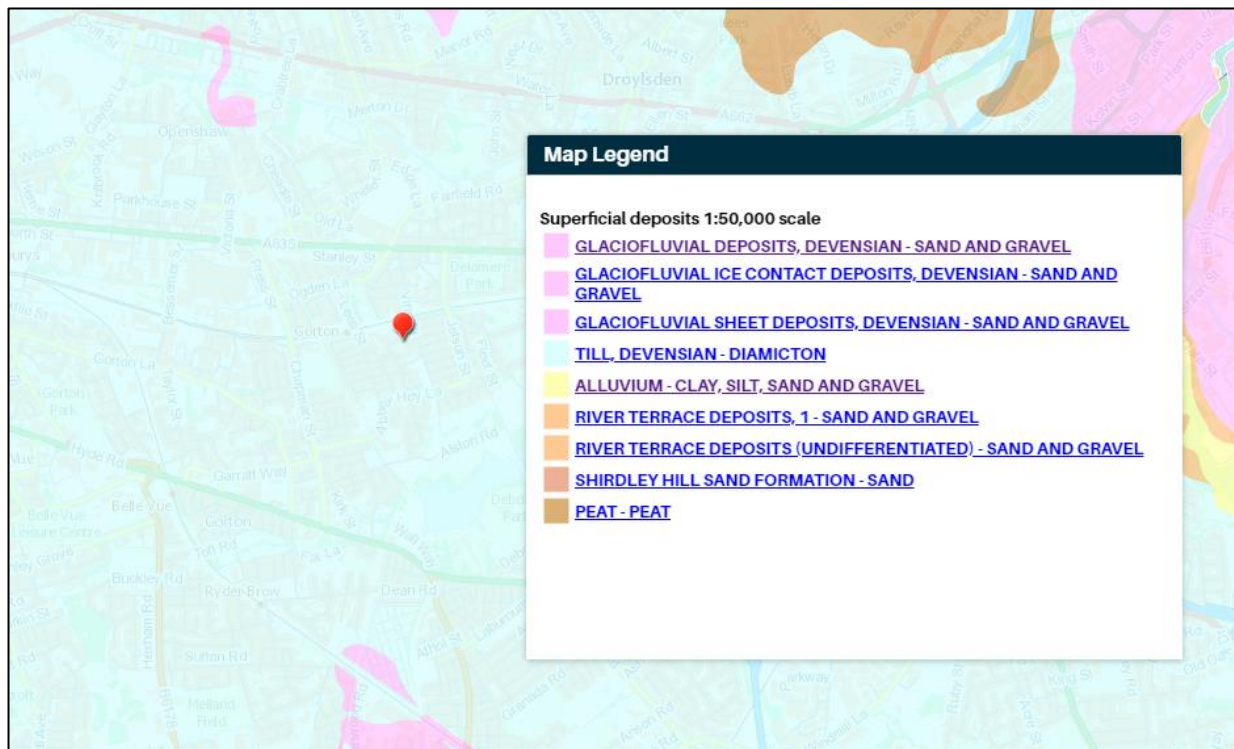
Two ground investigations have been produced for the application site by Cooper Associated (2006) and REC Ltd (2013). Latest ground investigation was undertaken by e3p in January 2022 and comprised of the following exploratory holes:

- 4 No. cable percussive boreholes to a maximum of 15.5m.
- 6 No. windowless sampler boreholes to a maximum depth of 3.9m.
- 8 No. machine excavated trial pits to a maximum depth of 2.7m.

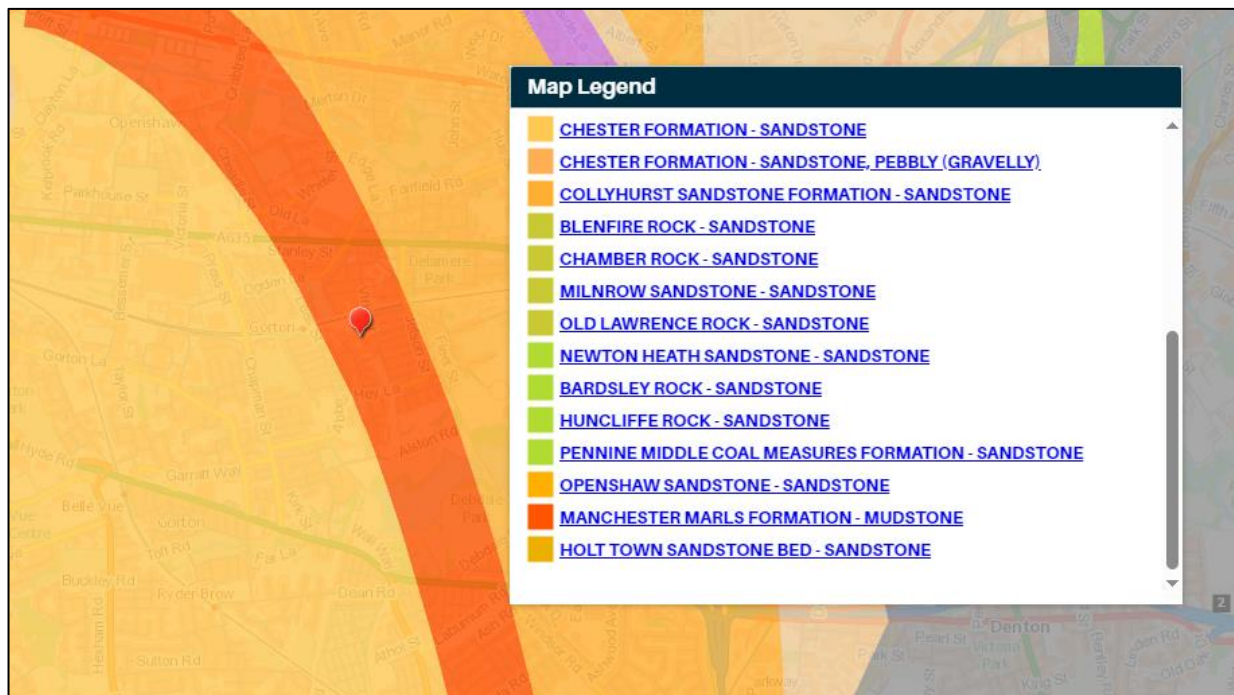
Made Ground was encountered in all exploratory holes with a thickness between 7.5m and 11.0m and is typically described as dark brown/grey clayey sandy gravel. Gravel is fine to coarse angular to subrounded of mudstone, sandstone, brick, glass, ash, ceramic, and concrete.

Till is encountered in all exploratory holes that penetrated the Made Ground and both clay and sand were recorded in this layer.

Figure 3.3-1: Mapped Superficial Soils



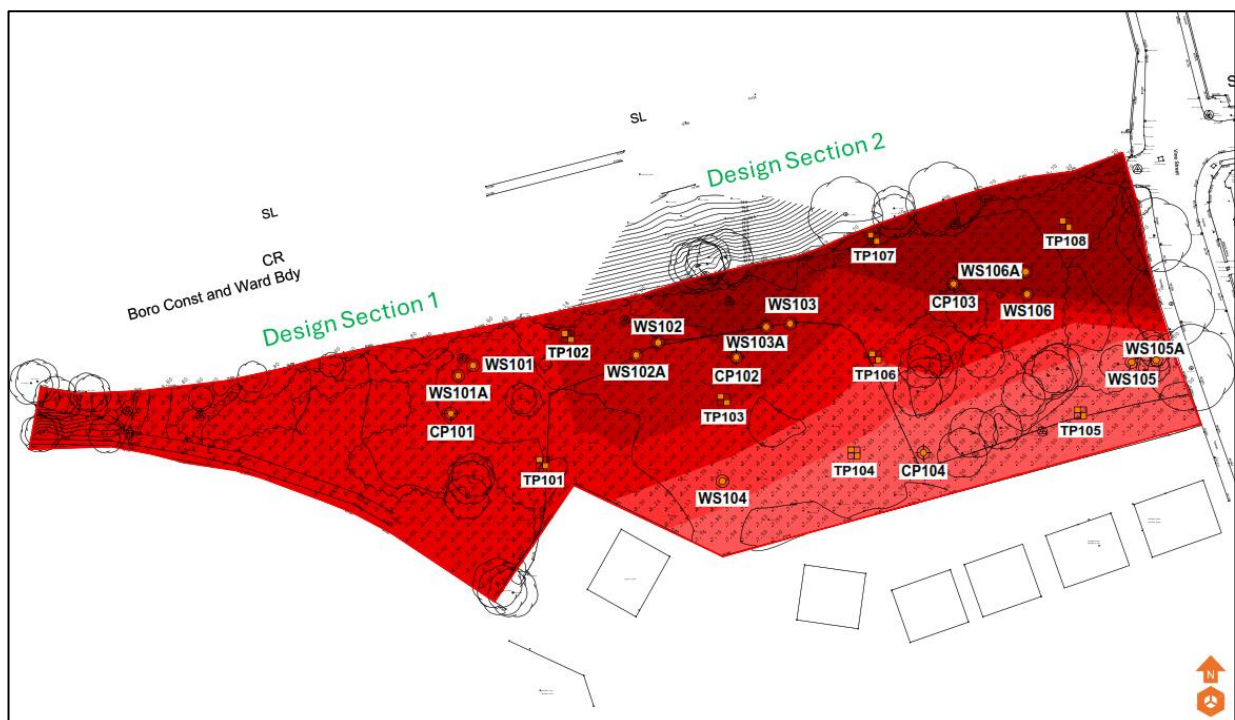
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Figure 3.3-2: Mapped Bedrock

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Figure 3.3-3: 1914 Ordnance Survey Map Superimposed on satellite Photograph

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Figure 3.3-4: Exploratory holes plan Superimposed on 1946 RAF Photograph**Figure 3.3-5: Exploratory Holes Locations**

The following ground model was used for analysis based on the available information:

Table 3.3-1: Ground Model

Top Level (mOD)	Base Level (mOD)	Thickness (m)	Strata	Description
Design Section 1				
81.5	72.2	9.3	Made Ground	Loose to dense granular
72.2	-	-	Till	Stiff to very stiff clay
Design Section 2				
82.0	71.0	11.0	Made Ground	Loose to dense granular
71.0	-	-	Till	Stiff to very stiff clay

The soil parameters and groundwater information used in the slope stability assessment are based on site-specific ground investigations and historical data. The soil primarily consists of Made Ground, which is loose to dense granular material with thicknesses ranging from 9.3 meters in Design Section 1 and 11 meters in Design Section 2, overlaying Till, a stiff to very stiff clay. Table below presents geotechnical parameters used for the slope stability assessment:

Table 3.3-2: Soil Parameters

Material description	Thickness (m)	Unit weight (kN/m ³)	Cohesion (kPa)	Friction angle (deg)
Made Ground	9.3	18.0	4	36
Till	20+	20.0	100	-

The groundwater information from cable percussive data was used at approximately 7.5m below the top level of the embankment. However, during the temporary works, if water-related issues such as seepage or excessive groundwater accumulation are observed, it may be necessary to implement a temporary dewatering system. This system would help to control the water levels, ensuring that excess pore water pressure does not negatively impact the stability of the slope or hinder the installation of the sheet pile retaining walls.

3.4 Slope Stability Analysis

The following information is available for the retaining sheet pile walls design and has been used in the slope stability assessment:

Design Section 1:

- This section is located at the western end of the site and covers approximately 74m of the wall.
- The retaining sheet pile walls are formed of Arcelor Mittal AZ18-700 grade S355 GP steel.
- The overall height of the embankment slope is 9m and the closest piling activity for the proposed houses is approximately 2m behind the wall and the slope crest.
- The existing slope angle to the horizontal is 40 degrees
- Network railway line is located at approximately 72.5mOD at a cutting at the toe of the slope
- The 2316 vibratory hammer will be utilised to drive the sheet piles to specified depth
- Surcharge of 273kPa with width of 1.48m is considered to account for piling works at the top of the slope

Design Section 2:

- This section is located at the eastern end of the site and covers the remaining 91m of the wall
- The retaining sheet pile walls are formed of Arcelor Mittal AZ18-700 grade S355 GP steel.
- The height of the embankment slope varies in this section and the closest piling activity for the proposed houses is approximately 5m behind the wall and 8m behind the slope crest.
- Network railway line is located at approximately 72.5mOD at a cutting at the toe of the slope
- The 2316 vibratory hammer will be utilised to drive the sheet piles to specified depth
- Surcharge of 273kPa with width of 1.48m is considered to account for piling works at the top of the slope

The following information is assumed for the slope stability assessment:

- The retaining sheet pile walls design is adequate and will not fail.
- A Peak Particle Velocity (PPV) of 5.1 to 50.8 mm/s has been assumed in the slope stability analysis with reference to recommendations provided by Federal Transit Administration (FTA) Transit Noise and Vibration Impact Assessment Manual dated September 2018 and BS 5228-2:2009+A1:2014 Code of Practice for Noise and Vibration Control on Construction and Open Sites – Part 2: Vibration.
- A Peak Ground Acceleration of 0.1g-0.2g is assumed with reference to available publications for ground vibrations cause by pile driving by I.A. Hosking et al. (1988), C.H. Dowding (1966), P.B. Attewell et al. (1973) and R.A.P. Bement (1996).
- Based on aerial and satellite imagery of site, existence of loose to dense vegetation and trees are observed on the slope. With reference to G0054B A4 Guidance Earth Structures and S1054 A5 Standard Category 1 Civil Engineering Earth Structures, roots of vegetations and trees can significantly contribute to stability of slopes. Therefore, root cohesion of up to 7kPa is assumed with this assessment up to 1m depth of slope.

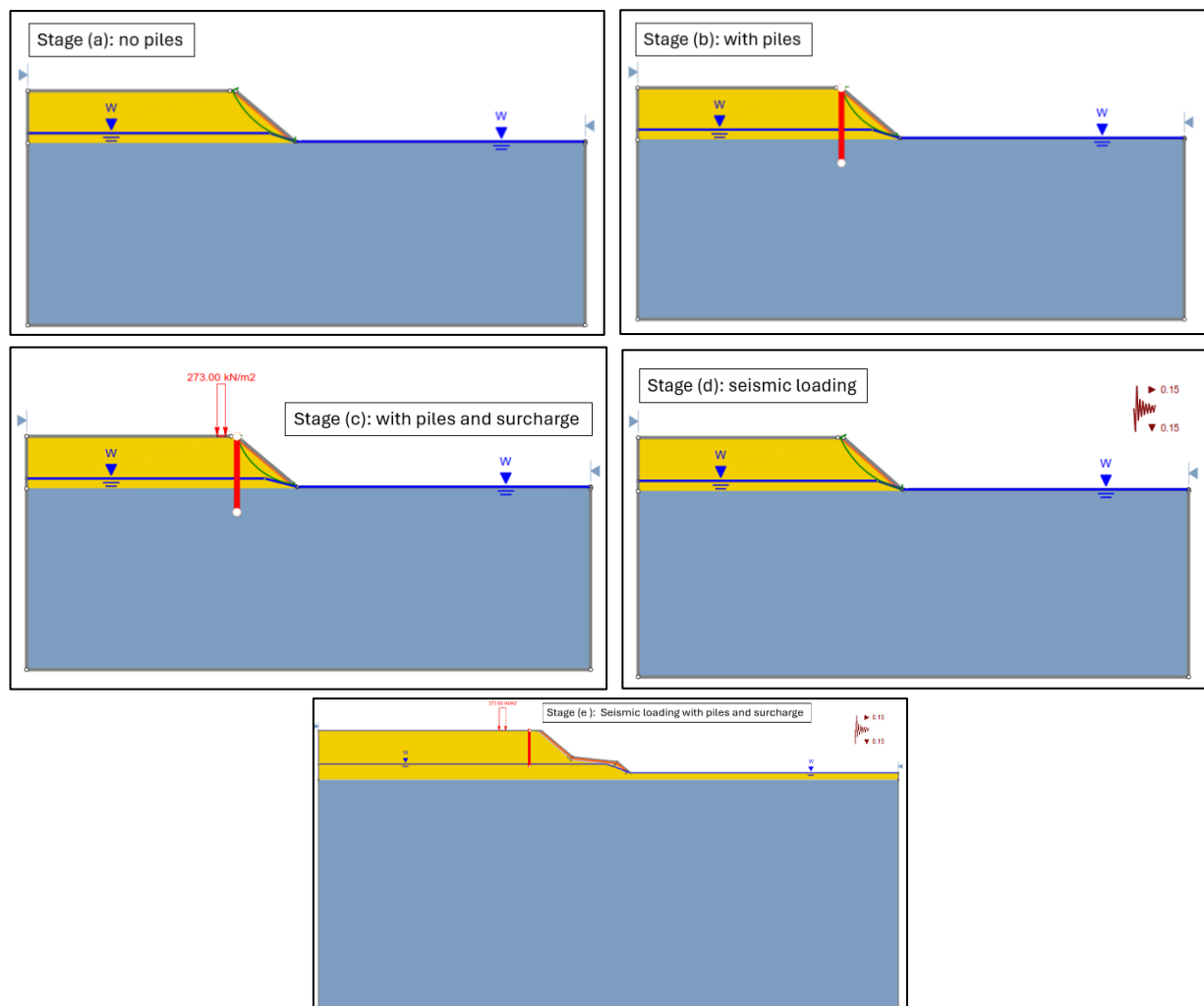
3.4.1 Slope Stability Procedure

The slope stability analysis was undertaken to assess the impact of temporary works pile installation on existing slope and adjacent Network Rail line.

The summary of structural analysis is provided below, and full report is included in Appendix 1:

- Slope stability assessment was undertaken using 2D Slope Stability Software Slide2.
- Slope stability analysis was undertaken for 2 Design Sections as explained in the previous section of this report.
- Each analysis comprises of several stages comprising of stability checks with no piles, with piles, with surcharge loading and under seismic conditions as presented below.

Figure 3.4-1: Slope Stability Assessment Stages



(a) No piles 1, (b) With piles, (c) With piles and surcharge loading, (d) Seismic loading, (e) Seismic loading with piles and surcharge

Factor of safety for each stage was calculated and is presented in the below table.

Table 3.4-1: Factory of safety for each stage

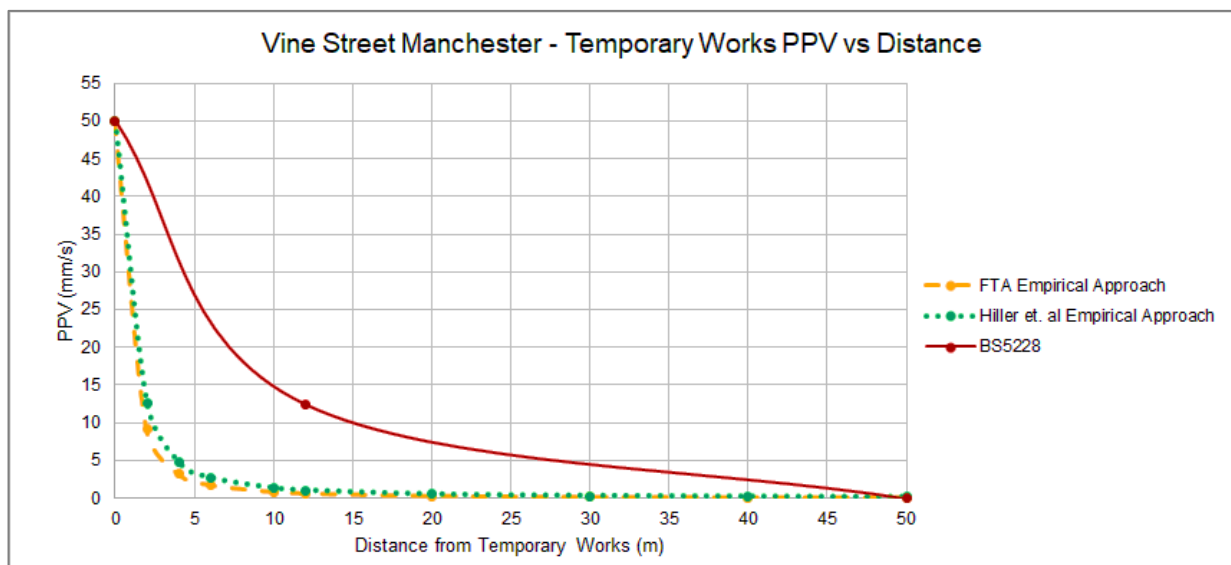
Stage	Design Section 1			Design Section 2		
	DA1-C1	DA1-C2	Seismic*	DA1-C1	DA1-C2	Seismic*
No piles	1.25	1.07	-	1.54	1.30	-
With piles	1.31	1.12	-	1.54	1.31	-
With piles and surcharge	1.31	1.12	-	1.54	1.31	-
Seismic loading	-	-	1.04	-	-	1.24
Seismic loading with piles	-	-	1.10	-	-	1.24

*Partial factor of 1.0 used for actions and materials.

3.5 Peak Particle Velocity (PPV)

The predicted PPV values during temporary piling works are calculated based on available literature, historic data, and applicable standards such as BS5228 and BS 785. However, actual PPV values can only be confirmed by monitoring at site.

With reference to empirical approaches of vibrations predictions of foundation installation activities proposed by Hiller and Crabb (2000), historic case data on vibrations levels measured for similar piling works in the Manchester area in BS5228 and BS7385, the below predicted PPV values are anticipated.

Figure 3.5-1: Predicted PPV Values due to temporary piling works

The predicted PPV values were calculated using two established empirical correlations, with a reference PPV value of 50.8 mm/s at the temporary piling location (distance = 0). Additionally, an upper and lower bound of 50.8 mm/s at the piling location (distance = 0) and 12.5 mm/s at the railway line (approximately 12m away) was considered as a worst-case scenario. This is based on historical data on vibration levels measured for similar piling works in the Manchester area and guidance provided in BS5228 and BS7385.

The actual PPV values are anticipated to fall within this range, however, verification through on-site monitoring is required to confirm the predictions.

3.6 Monitoring and Mitigation Works

Based on slope stability analysis, monitoring PPV values are recommended at site to verify slope stability and behaviour and establish mitigation and monitoring response in case of variant than expected conditions at site.

3.6.1 Mitigation Measures

It is recommended that the temporary piling works commence from Design Section 2, as this section has a lower slope height, a lower bench and a higher factor of safety for slope stability which suggests a safer starting point for the piling activities. It is recommended that the PPV values are monitored at this section and any potential slope failure at this section would be distal from the railway due to the presence of the lower bench in this section, reducing immediate risk and limiting the impact of any potential shallow failures on the adjacent Network Rail asset.

Based on observations and findings during the pile installation at Section 2, further control measures will be implemented as necessary. These may include using alternative driving equipment or adjusting the pile installation method to ensure safety and stability.

4 Summary and Conclusions

Key GeoSolutions Ltd (KGS) was commissioned by Earthwork Support Specialist (CE) Ltd to perform a slope stability assessment for the temporary works associated with installing retaining sheet pile walls at Vine Street, Gorton, Manchester. The purpose of the assessment is to evaluate the impact of the piling works on the adjacent Network Rail slope and railway. This report assessed potential risks, mitigation measures, and established monitoring works for the slope stability during the works.

The analysis considered the potential dynamic effects of the piling works, with specific focus on the use of the 2316 vibratory hammer for sheet pile driving. The assessment involved several stages, including slope stability checks without piles, with piles, with surcharge loading, and under seismic conditions.

Results of the stability assessment showed acceptable factors of safety under the various conditions examined. The seismic loading conditions resulted in the lowest but acceptable FOS values suggesting slope stability during pile driving works. In addition to the slope stability assessment, monitoring and mitigation measures were proposed to ensure slope stability during the works, and additional considerations were made regarding the potential stabilising effects of vegetation roots on the slope.

The predicted PPV values during temporary piling works were calculated using empirical correlations, historical case data, and standards such as BS5228 and BS7385. A reference PPV value of 50.8 mm/s at the piling location (distance = 0) was assumed, with an upper and lower bound ranging from 50.8 mm/s at the piling location to 12.5 mm/s at the railway line (approximately 12 m away) as a worst-case scenario.

It is recommended that the temporary piling works begin at Design Section 2, as it presents a safer starting point due to its lower slope height, lower bench, and higher factor of safety for slope stability. This approach minimises immediate risks and limits the impact of potential shallow failures on the nearby Network Rail assets. It is recommended that the PPV is monitored, and based on the findings during pile installation, further control measures, such as adjusting the equipment or installation method, will be implemented as needed to ensure continued safety and stability.

5 Summary of Geotechnical Risks

5.1 Risk Assessment

Table 5.1-1: Risk Classification Matrix

Likelihood		Severity				
		1 Minor	2 Moderate	3 Serious	4 Major	5 Catastrophic
1	Extremely Unlikely	1	2	3	4	5
2	Unlikely	2	4	6	8	10
3	Likely	3	6	9	12	15
4	Extremely Likely	4	8	12	16	20
5	Almost Certain	5	10	15	20	25

Table 5.1-2: Risk Classification Definitions

Risk Classification	
Low (1 to 8)	Ensure assumed control measures are maintained and reviewed as necessary.
Medium (9 to 19)	Additional control measures needed to reduce risk rating to a level that is equivalent to a test of “reasonably required” for.
High (20 to 25)	Activity not permitted. Hazard to be avoided or risk to be reduced to a tolerable level.

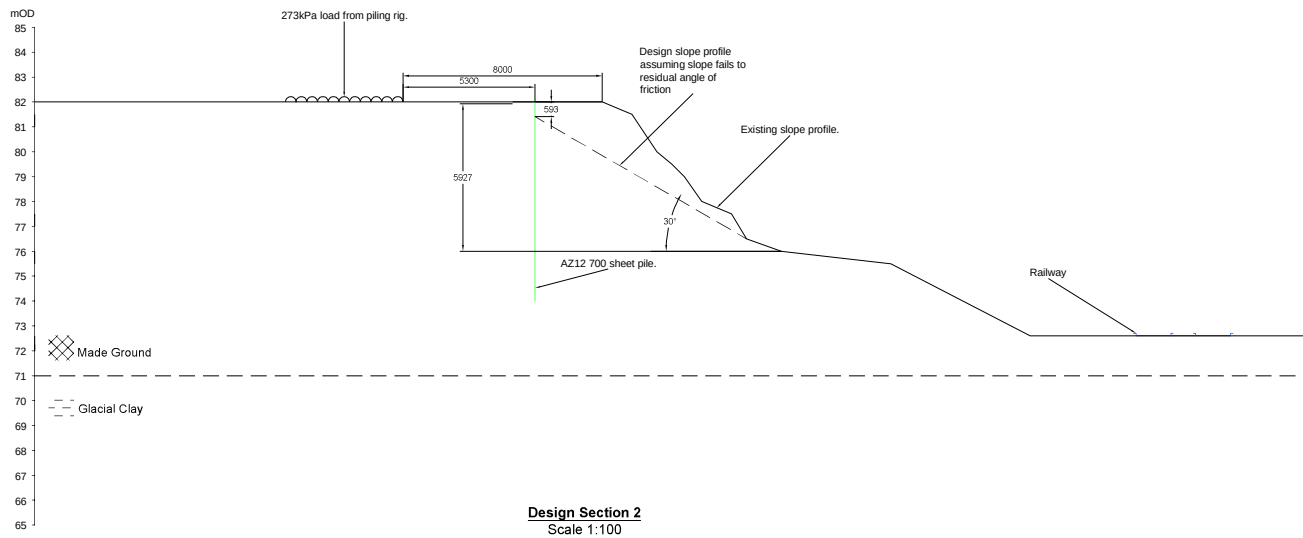
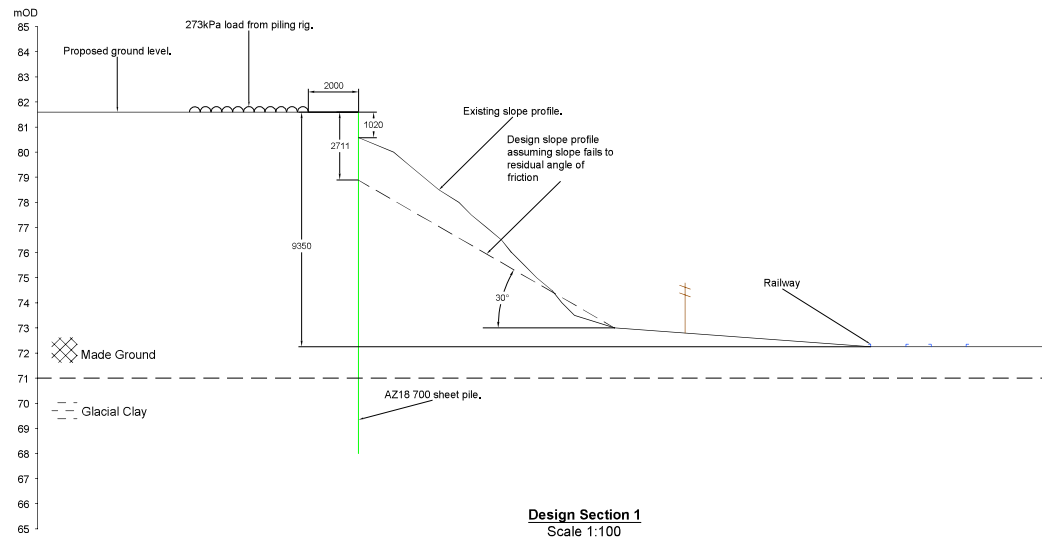
Table 5.1-3: Potential Severity Definitions

Potential Severity of Harm Occurring		
1	Minor	Minor damage or loss (no human injury)
2	Moderate	Moderate damage or loss (slight injury or illness)
3	Serious	Substantial damage or loss (serious injury or illness)
4	Major	Major damage or loss (fatal injury or illness)
5	Catastrophic	Catastrophic loss or damage (multiple fatalities)

Table 5.1-4: Risk Matrix

Risk ID	Hazard	Consequence	(L)	(S)	Risk	Mitigation	(L)	(S)	Residual Risk
1	Ground conditions could be poorer than anticipated.	Slope instability or failure	3	4	12	Monitoring to be established on the slope and stability of slope monitored during piling works.	1	4	4
2	Excessive surcharge	Slope instability or failure	2	4	8	Slope stability assessment undertaken assuming 273kPa surcharge. The contractor to ensure specified surcharge is not exceeded.	1	4	4
3	Failure of retaining sheet piles	Slope instability or failure	2	4	8	Slope stability assessment undertaken assuming pile design is adequate. The contractor to ensure specified pile design is implemented.	1	4	4

Appendix 1: Project Drawings



CDM 2015 :

See Appendix F of calculations

NOTES :

General

1. All dimensions mm UNO
2. All elevations mOD UNO
3. Do not scale, use figured dimensions only

REV	DESCRIPTIONS	DATE	BY	CHECK



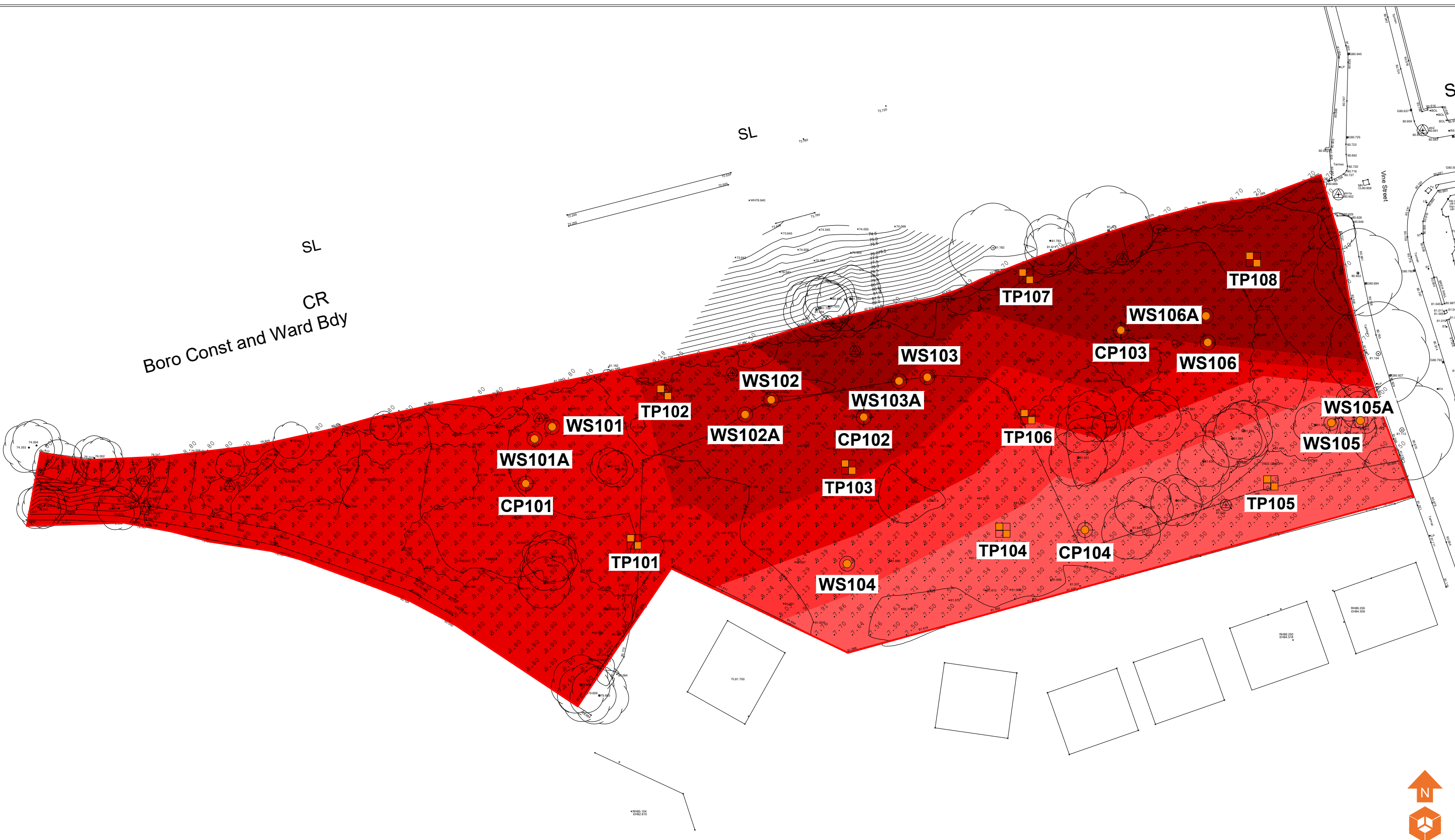
Client
Kirkland Development Limited

Project
Vine Street, Manchester

Title
Sheet Pile Retaining Wall Analysis Section

Drawing Status
FOR INFORMATION

DATE	BY	CHECK	SCALE	DRAWING NUMBER
20/09/2023	SJ		1:100	2004 - 001
20/09/2023	WF			
20/09/2023				



Location Symbols

- WS101: Approximate Window Sample Probehole Location
- TP101: Approximate Trial Pit Location

Made Ground Depth (m)

- Depth of Made Ground 7.00 - 7.49m
- Depth of Made Ground 7.50 - 7.99m
- Depth of Made Ground 8.00 - 8.49m
- Depth of Made Ground 8.50 - 8.99m
- Depth of Made Ground 9.00 - 9.50m
- Depth of Made Ground >9.50m

Notes:				
P1	REVB	09.12.2021	LM	AS
P1	REVA	07.12.2021	EB	AS
Phase	Issue	Date	Drawn	Checked

Client:

Kirkland

Job Title:

Vine Street,
Gorton

Job No:
14-944

Drawing No:
006

Date:
09.12.2021

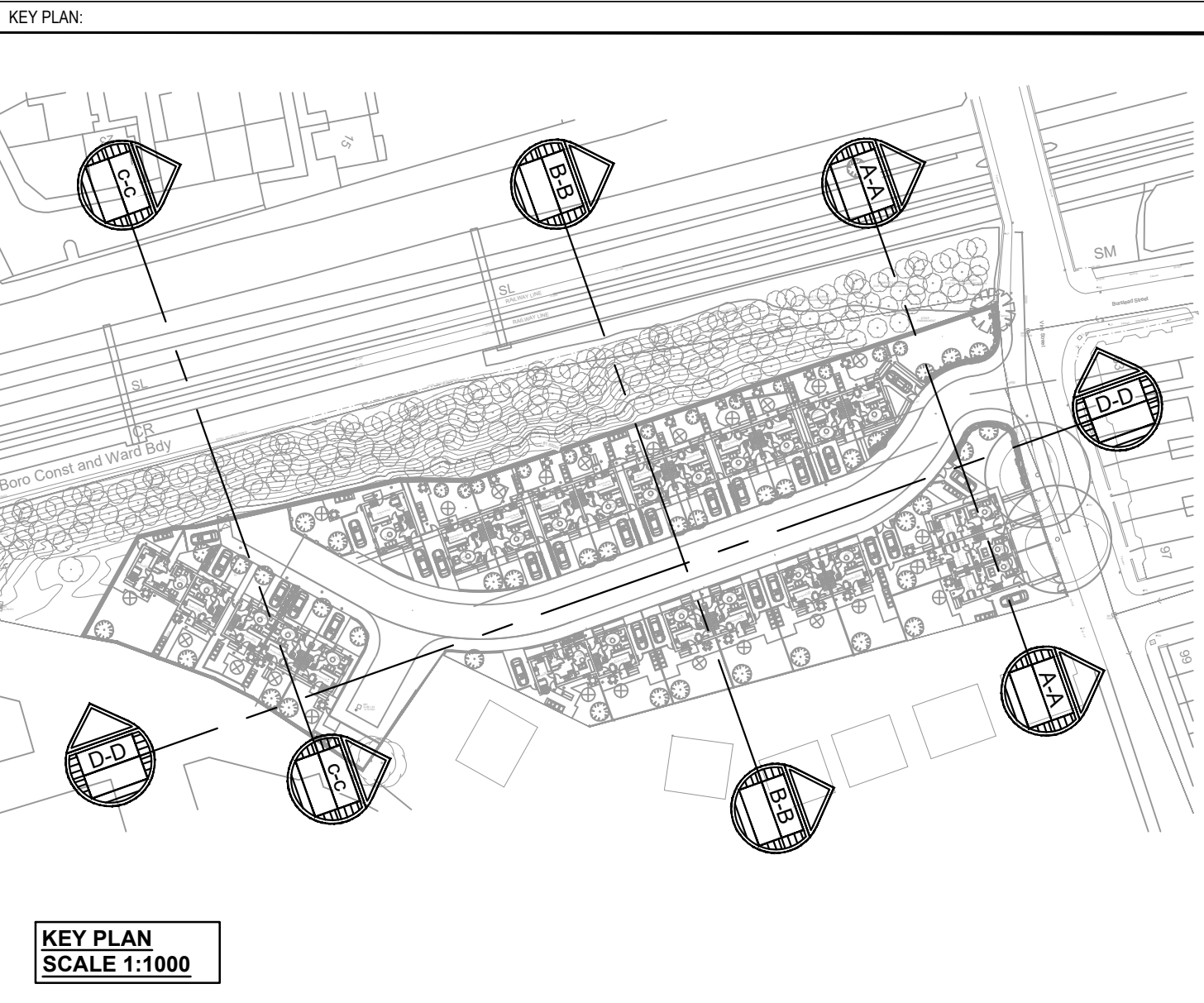
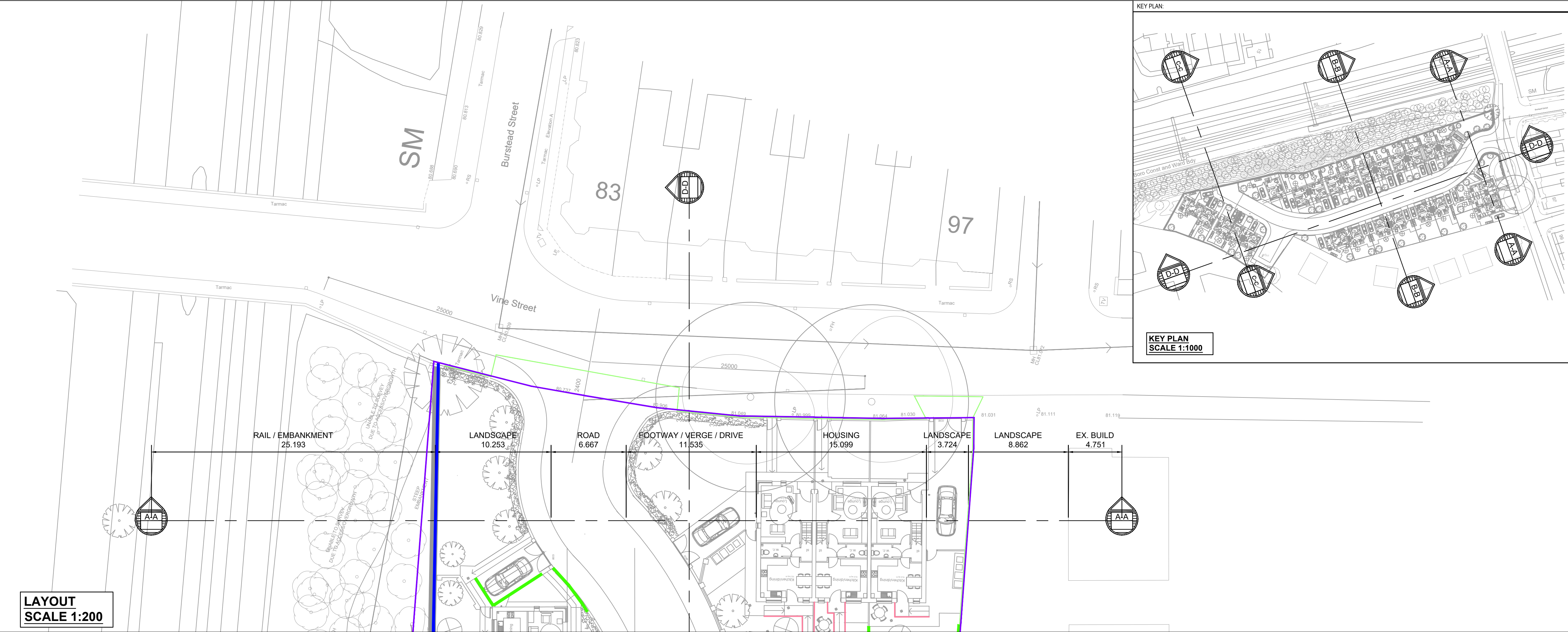
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Ground Plan

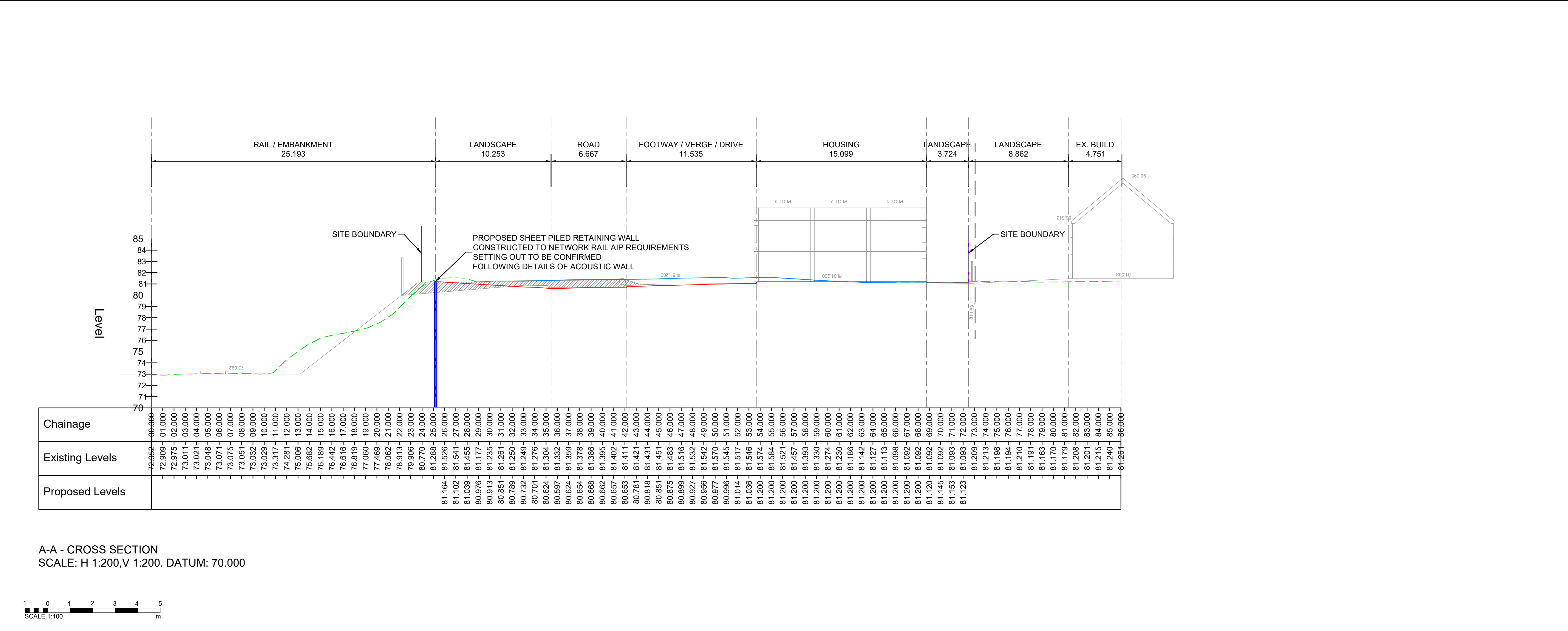


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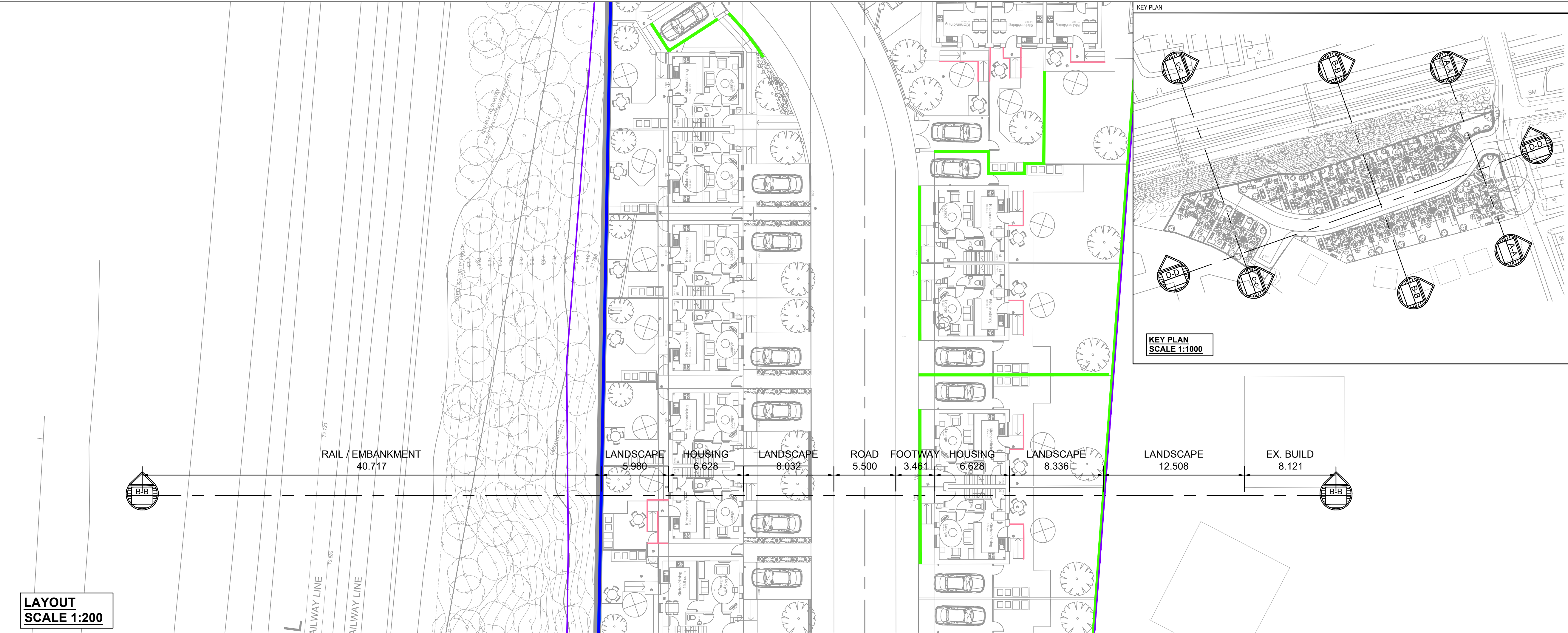
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DRAWING NOTES:			
---	EXISTING GROUND LEVEL / LIDAR PROFILE		
---	TOPOGRAPHICAL SURVEY REV C LEVEL PROFILE		
---	PROPOSED FINISHED LEVEL PROFILE		
---	PROPOSED SHEET PILED RETAINING WALL		
---	PROPOSED FLAG ON EDGE RETAINING		
---	SITE BOUNDARY		



P06	REVISED TO SUIT ARCHITECTS COMMENTS	05.05.23	LWP	PB
P05	REVISED TO SUIT ARCHITECTS COMMENTS	28.04.23	LWP	PB
P04	REVISED TO SUIT ARCHITECTS COMMENTS	19.04.23	LWP	PB
P03	REVISED TOPO SURVEY PROFILE ADDED	18.04.23	LWP	PB
P02	CROSS SECTIONS EXTENDED	18.04.23	LWP	PB
P01	ISSUED FOR COMMENT	14.04.23	LWP	PB
REV	DESCRIPTION	DATE	BY	CHKD
ORIGINATOR:				
RIDGE				
5TH FLOOR BELVEDERE HOUSE 12 BOOTH STREET MANCHESTER, M2 4AW				
TEL: 0161 833 9579 WWW.RIDGE.CO.UK				
CLIENT: KIRKLAND DEVELOPMENT LTD				
IN ASSOCIATION WITH:				
PROJECT: VINE STREET GORTON				
TITLE: PROPOSED FINISHED LEVELS CROSS SECTIONS SHEET 1				
ENG/TECH: LWP	CSE: PB	ICSE: PB	SCALE: 1:200	@ A1
STATUS: PRELIMINARY				
UNLESS ISSUED FOR CONSTRUCTION - WORKS AT CLIENT/CONTRACTORS RISK				
SUITABILITY: S0 - Initial Status or WIP				
PROJECT: VSG	ORG: RDG	ZONE: XX	LEVEL: XX	TYPE: DR
ROLE: C	NUMBER: 0004	REV: P06		



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DRAWING NOTES:

- EXISTING GROUND LEVEL / LIDAR PROFILE
- TOPOGRAPHICAL SURVEY REV C LEVEL PROFILE
- PROPOSED FINISHED LEVEL PROFILE
- PROPOSED SHEET PILED RETAINING WALL
- PROPOSED FLAG ON EDGE RETAINING
- SITE BOUNDARY

P06	REVISED TO SUIT ARCHITECTS COMMENTS	05.05.23	LWP	PB
P05	REVISED TO SUIT ARCHITECTS COMMENTS	28.04.23	LWP	PB
P04	REVISED TO SUIT ARCHITECTS COMMENTS	19.04.23	LWP	PB
P03	REVISED TO SUIT ARCHITECTS COMMENTS	19.04.23	LWP	PB
P02	REVISED TOPO SURVEY PROFILE ADDED	18.04.23	LWP	PB
P01	ISSUED FOR COMMENT	18.04.23	LWP	PB
REV	DESCRIPTION	DATE	BY	CHKD



5TH FLOOR
BELVEDERE HOUSE
12 BOOTH STREET
MANCHESTER, M2 4AW

TEL: 0161 833 9579
WWW.RIDGE.CO.UK

CLIENT:
KIRKLAND DEVELOPMENT LTD

IN ASSOCIATION WITH:

PROJECT:
VINE STREET
GORTON

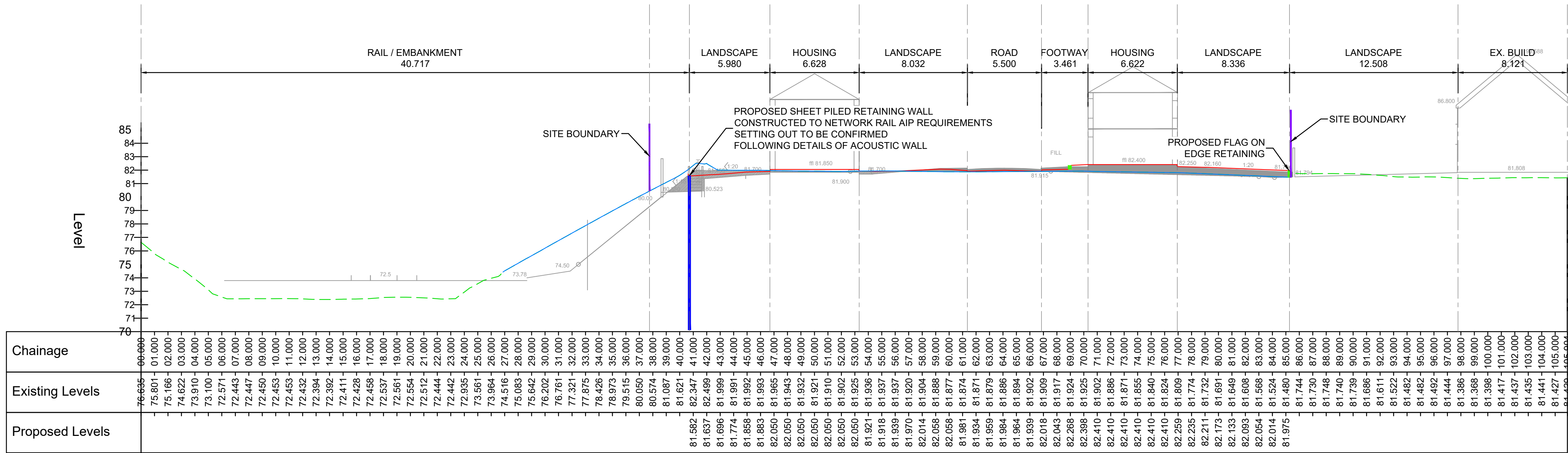
TITLE:
PROPOSED FINISHED LEVELS
CROSS SECTIONS
SHEET 2

ENG/TECH: LWP CSE: PB ICSE: PB SCALE: 1:200 @ A1 STATUS: PRELIMINARY

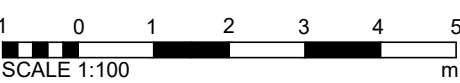
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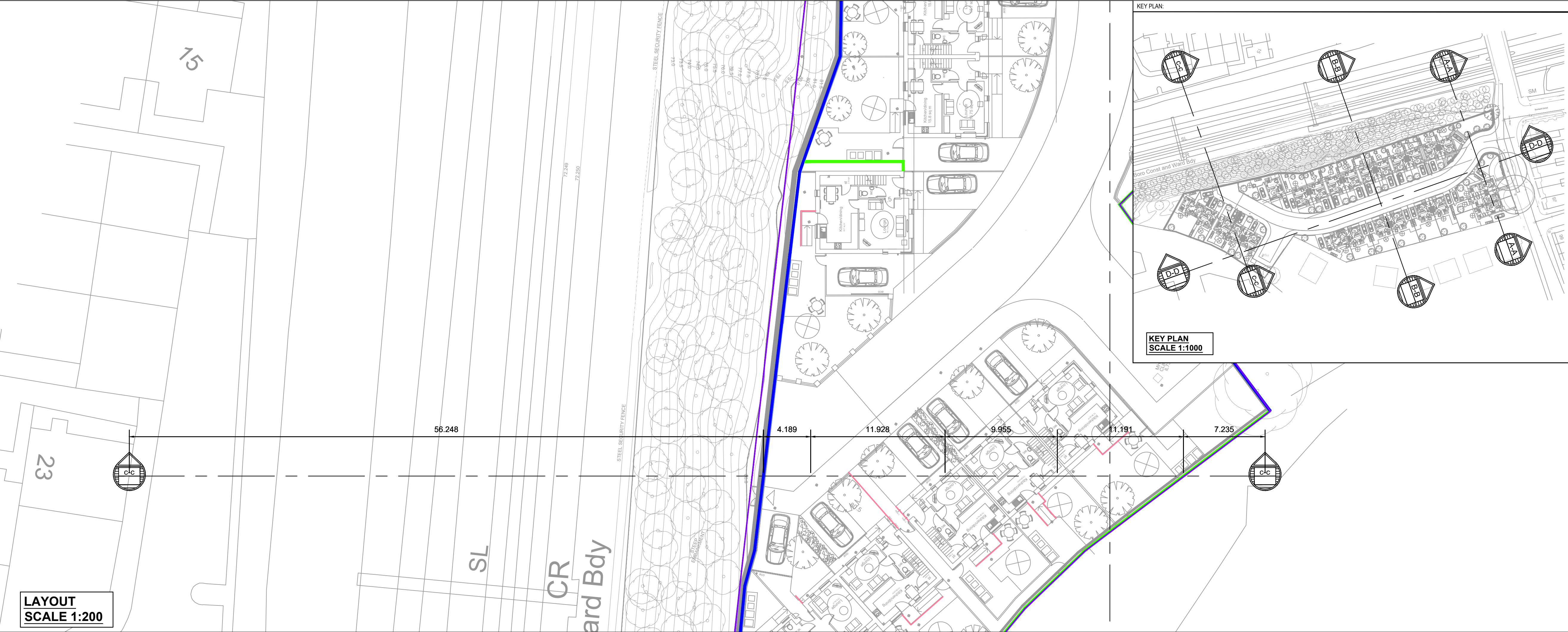
SUITABILITY: SO - Initial Status or WIP

PROJECT: VSG ORG: RDG ZONE: XX LEVEL: XX TYPE: DR ROLE: C NUMBER: 0005 REV: P06



B-B-CROSS SECTION
SCALE: H 1:200,V 1:200. DATUM: 70.000





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DRAWING NOTES:

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- TOPOGRAPHICAL SURVEY REV C LEVEL PROFILE
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- SITE BOUNDARY

P04	REVISED TO SUIT ARCHITECTS COMMENTS	05.05.23	LWP	PB
P03	REVISED TO SUIT ARCHITECTS COMMENTS	28.04.23	LWP	PB
P02	UPDATED TO SUIT REVISED LEVELS	21.04.23	LWP	PB
P01	ISSUED FOR COMMENT	19.04.23	LWP	PB
REV	DESCRIPTION	DATE	BY	CHKD



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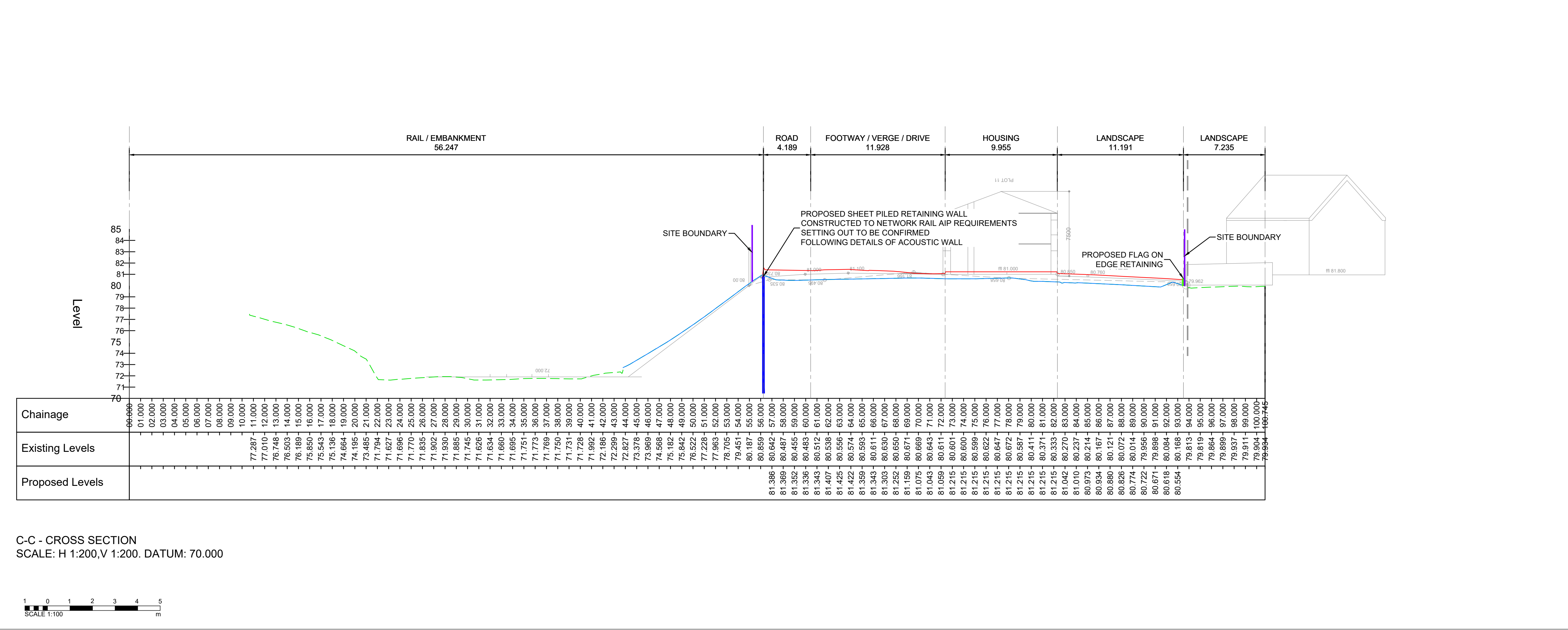
CLIENT:
KIRKLAND DEVELOPMENT LTD

IN ASSOCIATION WITH:

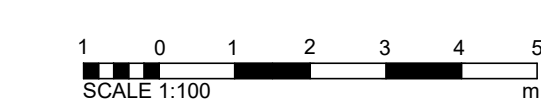
PROJECT:
**VINE STREET
GORTON**

TITLE:
**PROPOSED FINISHED LEVELS
CROSS SECTIONS
SHEET 3**

ENG/TECH: LWP	CSE: PB	ICSE: PB	SCALE: 1:200	@ A1
STATUS: PRELIMINARY				
UNLESS ISSUED FOR CONSTRUCTION - WORKS AT CLIENT/CONTRACTORS RISK				
SUITABILITY: S0 - Initial Status or WIP				
PROJECT: VSG	ORG: RDG	ZONE: XX	LEVEL: XX	TYPE: DR
ROLE: C	NUMBER: 0006	REV: P04		



C-C - CROSS SECTION
SCALE: H 1:200,V 1:200. DATUM: 70.000



Appendix 2: Slope Stability Report

