Results - Single Stage WAC

Project: 22-0874 Dublin Central

Chemtest Job No:	22-45980				Landfill Waste Acceptance Criteria Limits		
Chemtest Sample ID:	1555332						
Sample Ref:					Inert Waste Landfill	Stable, Non-reactive hazardous waste in non-hazardous Landfill	Hazardous Waste Landfill
Sample ID:							
Sample Location:	DC-BH107						
Top Depth(m):	10.00						
Bottom Depth(m):							
Sampling Date:	28-Nov-2022						
Determinand	**SOP**	**Accred.**	**Units**				
Total Organic Carbon	2625	M	%	0.55	3	5	6
Loss On Ignition	2610	M	%	1.6	--	--	10
Total BTEX	2760	M	mg/kg	< 0.010	6	--	--
Total PCBs (7 Congeners)	2815	M	mg/kg	< 0.10	1	--	--
TPH Total WAC	2670	M	mg/kg	< 10	500	--	--
Total (Of 17) PAH's	2800	N	mg/kg	< 2.0	100	--	--
pH	2010	M		8.9	--	>6	--
Acid Neutralisation Capacity	2015	N	mol/kg	0.0050	--	To evaluate	To evaluate
Eluate Analysis			**10:1 Eluate mg/l**	**10:1 Eluate mg/kg**	**Limit values for compliance leaching test using BS EN 12457 at L/S 10 l/kg**		
Arsenic	1455	U	0.0005	0.0049	0.5	2	25
Barium	1455	U	< 0.005	< 0.050	20	100	300
Cadmium	1455	U	< 0.00011	< 0.0011	0.04	1	5
Chromium	1455	U	< 0.0005	< 0.0050	0.5	10	70
Copper	1455	U	< 0.0005	< 0.0050	2	50	100
Mercury	1455	U	< 0.00005	< 0.00050	0.01	0.2	2
Molybdenum	1455	U	0.0018	0.019	0.5	10	30
Nickel	1455	U	< 0.0005	< 0.0050	0.4	10	40
Lead	1455	U	< 0.0005	< 0.0050	0.5	10	50
Antimony	1455	U	< 0.0005	< 0.0050	0.06	0.7	5
Selenium	1455	U	< 0.0005	< 0.0050	0.1	0.5	7
Zinc	1455	U	< 0.003	< 0.025	4	50	200
Chloride	1220	U	< 1.0	< 10	800	15000	25000
Fluoride	1220	U	0.11	1.1	10	150	500
Sulphate	1220	U	3.7	37	1000	20000	50000
Total Dissolved Solids	1020	N	41	410	4000	60000	100000
Phenol Index	1920	U	< 0.030	< 0.30	1	-	-
Dissolved Organic Carbon	1610	U	2.9	< 50	500	800	1000

Solid Information	
Dry mass of test portion/kg	0.090
Moisture (%)	7.4

Waste Acceptance Criteria

Landfill WAC analysis (specifically leaching test results) must not be used for hazardous waste classification purposes. This analysis is only applicable for hazardous waste landfill acceptance and does not give any indication as to whether a waste may be hazardous or non-hazardous.

Results - Single Stage WAC

Project: 22-0874 Dublin Central

					Landfill Waste Acceptance Criteria Limits		
Chemtest Job No:	22-45980						
Chemtest Sample ID:	1555333						
Sample Ref:							
Sample ID:							
Sample Location:	DC-BH107						
Top Depth(m):	13.00				**Inert Waste Landfill**	**Stable, Non-reactive hazardous waste in non-hazardous Landfill**	**Hazardous Waste Landfill**
Bottom Depth(m):							
Sampling Date:	28-Nov-2022						
Determinand	**SOP**	**Accred.**	**Units**				
Total Organic Carbon	2625	M	%	0.50	3	5	6
Loss On Ignition	2610	M	%	1.3	--	--	10
Total BTEX	2760	M	mg/kg	< 0.010	6	--	--
Total PCBs (7 Congeners)	2815	M	mg/kg	< 0.10	1	--	--
TPH Total WAC	2670	M	mg/kg	< 10	500	--	--
Total (Of 17) PAH's	2800	N	mg/kg	< 2.0	100	--	--
pH	2010	M		8.8	--	>6	--
Acid Neutralisation Capacity	2015	N	mol/kg	0.012	--	To evaluate	To evaluate
Eluate Analysis			**10:1 Eluate mg/l**	**10:1 Eluate mg/kg**	**Limit values for compliance leaching test using BS EN 12457 at L/S 10 l/kg**		
Arsenic	1455	U	0.0005	0.0050	0.5	2	25
Barium	1455	U	< 0.005	< 0.050	20	100	300
Cadmium	1455	U	< 0.00011	< 0.0011	0.04	1	5
Chromium	1455	U	< 0.0005	< 0.0050	0.5	10	70
Copper	1455	U	< 0.0005	< 0.0050	2	50	100
Mercury	1455	U	< 0.00005	< 0.00050	0.01	0.2	2
Molybdenum	1455	U	0.0033	0.033	0.5	10	30
Nickel	1455	U	< 0.0005	< 0.0050	0.4	10	40
Lead	1455	U	< 0.0005	< 0.0050	0.5	10	50
Antimony	1455	U	< 0.0005	< 0.0050	0.06	0.7	5
Selenium	1455	U	0.0018	0.018	0.1	0.5	7
Zinc	1455	U	< 0.003	< 0.025	4	50	200
Chloride	1220	U	1.8	18	800	15000	25000
Fluoride	1220	U	0.14	1.4	10	150	500
Sulphate	1220	U	3.9	39	1000	20000	50000
Total Dissolved Solids	1020	N	46	460	4000	60000	100000
Phenol Index	1920	U	< 0.030	< 0.30	1	-	-
Dissolved Organic Carbon	1610	U	< 2.5	< 50	500	800	1000

Solid Information	
Dry mass of test portion/kg	0.090
Moisture (%)	5.5

Waste Acceptance Criteria

Landfill WAC analysis (specifically leaching test results) must not be used for hazardous waste classification purposes. This analysis is only applicable for hazardous waste landfill acceptance and does not give any indication as to whether a waste may be hazardous or non-hazardous.

Test Methods

SOP	Title	Parameters included	Method summary
1010	pH Value of Waters	pH	pH Meter
1020	Electrical Conductivity and Total Dissolved Solids (TDS) in Waters	Electrical Conductivity and Total Dissolved Solids (TDS) in Waters	Conductivity Meter
1220	Anions, Alkalinity & Ammonium in Waters	Fluoride; Chloride; Nitrite; Nitrate; Total; Oxidisable Nitrogen (TON); Sulfate; Phosphate; Alkalinity; Ammonium	Automated colorimetric analysis using 'Aquakem 600' Discrete Analyser.
1455	Metals in Waters by ICP-MS	Metals, including: Antimony; Arsenic; Barium; Beryllium; Boron; Cadmium; Chromium; Cobalt; Copper; Lead; Manganese; Mercury; Molybdenum; Nickel; Selenium; Tin; Vanadium; Zinc	Filtration of samples followed by direct determination by inductively coupled plasma mass spectrometry (ICP-MS).
1610	Total/Dissolved Organic Carbon in Waters	Organic Carbon	TOC Analyser using Catalytic Oxidation
1920	Phenols in Waters by HPLC	Phenolic compounds including: Phenol, Cresols, Xylenols, Trimethylphenols Note: Chlorophenols are excluded.	Determination by High Performance Liquid Chromatography (HPLC) using electrochemical detection.
2010	pH Value of Soils	pH	pH Meter
2015	Acid Neutralisation Capacity	Acid Reserve	Titration
2030	Moisture and Stone Content of Soils(Requirement of MCERTS)	Moisture content	Determination of moisture content of soil as a percentage of its as received mass obtained at <37°C.
2040	Soil Description(Requirement of MCERTS)	Soil description	As received soil is described based upon BS5930
2120	Water Soluble Boron, Sulphate, Magnesium & Chromium	Boron; Sulphate; Magnesium; Chromium	Aqueous extraction / ICP-OES
2180	Sulphur (Elemental) in Soils by HPLC	Sulphur	Dichloromethane extraction / HPLC with UV detection
2192	Asbestos	Asbestos	Polarised light microscopy / Gravimetry
2300	Cyanides & Thiocyanate in Soils	Free (or easy liberatable) Cyanide; total Cyanide; complex Cyanide; Thiocyanate	Allkaline extraction followed by colorimetric determination using Automated Flow Injection Analyser.
2325	Sulphide in Soils	Sulphide	Steam distillation with sulphuric acid / analysis by 'Aquakem 600' Discrete Analyser, using N,N–dimethyl-p-phenylenediamine.
2430	Total Sulphate in soils	Total Sulphate	Acid digestion followed by determination of sulphate in extract by ICP-OES.
2455	Acid Soluble Metals in Soils	Metals, including: Arsenic; Barium; Beryllium; Cadmium; Chromium; Cobalt; Copper; Lead; Manganese; Mercury; Molybdenum; Nickel; Selenium; Vanadium; Zinc	Acid digestion followed by determination of metals in extract by ICP-MS.
2490	Hexavalent Chromium in Soils	Chromium [VI]	Soil extracts are prepared by extracting dried and ground soil samples into boiling water. Chromium [VI] is determined by 'Aquakem 600' Discrete Analyser using 1,5-diphenylcarbazide.
2610	Loss on Ignition	loss on ignition (LOI)	Determination of the proportion by mass that is lost from a soil by ignition at 550°C.
2625	Total Organic Carbon in Soils	Total organic Carbon (TOC)	Determined by high temperature combustion under oxygen, using an Eltra elemental analyser.
2670	Total Petroleum Hydrocarbons (TPH) in Soils by GC-FID	TPH (C6–C40); optional carbon banding, e.g. 3-band – GRO, DRO & LRO*TPH C8–C40	Dichloromethane extraction / GC-FID
2680	TPH A/A Split	Aliphatics: >C5–C6, >C6–C8,>C8–C10, >C10–C12, >C12–C16, >C16–C21, >C21–C35, >C35– C44Aromatics: >C5–C7, >C7–C8, >C8– C10, >C10–C12, >C12–C16, >C16– C21, >C21– C35, >C35– C44	Dichloromethane extraction / GCxGC FID detection

Test Methods

SOP	Title	Parameters included	Method summary
2760	Volatile Organic Compounds (VOCs) in Soils by Headspace GC-MS	Volatile organic compounds, including BTEX and halogenated Aliphatic/Aromatics.(cf. USEPA Method 8260)*please refer to UKAS schedule	Automated headspace gas chromatographic (GC) analysis of a soil sample, as received, with mass spectrometric (MS) detection of volatile organic compounds.
2800	Speciated Polynuclear Aromatic Hydrocarbons (PAH) in Soil by GC-MS	Acenaphthene*; Acenaphthylene; Anthracene*; Benzo[a]Anthracene*; Benzo[a]Pyrene*; Benzo[b]Fluoranthene*; Benzo[ghi]Perylene*; Benzo[k]Fluoranthene; Chrysene*; Dibenz[ah]Anthracene; Fluoranthene*; Fluorene*; Indeno[123cd]Pyrene*; Naphthalene*; Phenanthrene*; Pyrene*	Dichloromethane extraction / GC-MS
2815	Polychlorinated Biphenyls (PCB) ICES7Congeners in Soils by GC-MS	ICES7 PCB congeners	Acetone/Hexane extraction / GC-MS
2920	Phenols in Soils by HPLC	Phenolic compounds including Resorcinol, Phenol, Methylphenols, Dimethylphenols, 1-Naphthol and TrimethylphenolsNote: chlorophenols are excluded.	60:40 methanol/water mixture extraction, followed by HPLC determination using electrochemical detection.
640	Characterisation of Waste (Leaching C10)	Waste material including soil, sludges and granular waste	ComplianceTest for Leaching of Granular Waste Material and Sludge

Report Information

Key	
U	UKAS accredited
M	MCERTS and UKAS accredited
N	Unaccredited
S	This analysis has been subcontracted to a UKAS accredited laboratory that is accredited for this analysis
SN	This analysis has been subcontracted to a UKAS accredited laboratory that is not accredited for this analysis
T	This analysis has been subcontracted to an unaccredited laboratory
I/S	Insufficient Sample
U/S	Unsuitable Sample
N/E	not evaluated
<	"less than"
>	"greater than"
SOP	Standard operating procedure
LOD	Limit of detection

Comments or interpretations are beyond the scope of UKAS accreditation
The results relate only to the items tested
Uncertainty of measurement for the determinands tested are available upon request
None of the results in this report have been recovery corrected
All results are expressed on a dry weight basis

The following tests were analysed on samples as received and the results subsequently corrected to a dry weight basis TPH, BTEX, VOCs, SVOCs, PCBs, Phenols

For all other tests the samples were dried at < 37°C prior to analysis
All Asbestos testing is performed at the indicated laboratory
Issue numbers are sequential starting with 1 all subsequent reports are incremented by 1

Sample Deviation Codes

A - Date of sampling not supplied
B - Sample age exceeds stability time (sampling to extraction)
C - Sample not received in appropriate containers
D - Broken Container
E - Insufficient Sample (Applies to LOI in Trommel Fines Only)

Sample Retention and Disposal

All soil samples will be retained for a period of 30 days from the date of receipt
All water samples will be retained for 14 days from the date of receipt
Charges may apply to extended sample storage

If you require extended retention of samples, please email your requirements to:
customerservices@chemtest.com

CAUSEWAY
GEOTECH

APPENDIX G

SPT HAMMER ENERGY MEASUREMENT REPORT

SPT Hammer Energy Test Report

in accordance with BSEN ISO 22476-3:2005

Southern Testing
Unit 11
Charlwoods Road
East Grinstead
West Sussex
RH19 2HU

SPT Hammer Ref:	RR14.
Test Date:	01/08/2022
Report Date:	02/08/2022
File Name:	RR14..spt
Test Operator:	NPB

Instrumented Rod Data

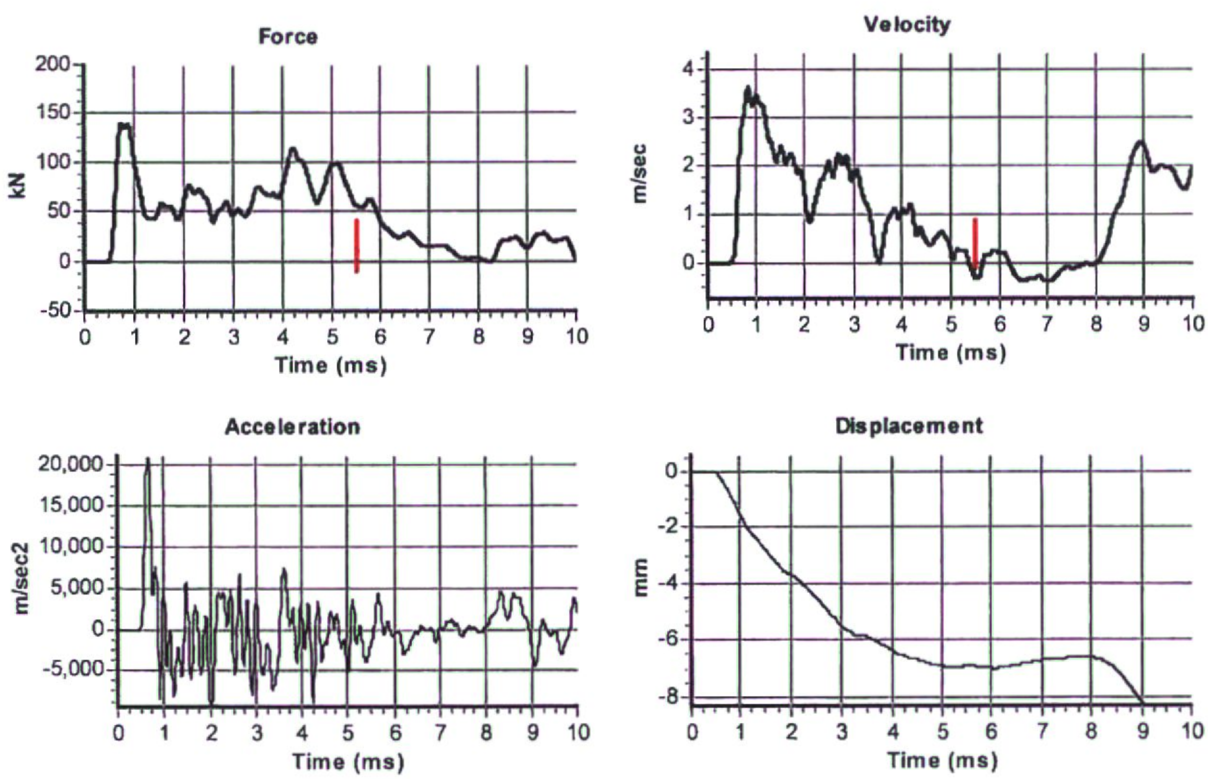
Diameter d_r (mm):	54
Wall Thickness t_r (mm):	6.7
Assumed Modulus E_a (GPa):	208
Accelerometer No.1:	64786
Accelerometer No.2:	64789

SPT Hammer Information

Hammer Mass m (kg):	63.5
Falling Height h (mm):	760
SPT String Length L (m):	11.0

Comments / Location

CAUSEWAY



Calculations

Area of Rod A (mm2):	996
Theoretical Energy E_{theor} (J):	473
Measured Energy E_{meas} (J):	509

Energy Ratio E_r (%): 108

The recommended calibration interval is 12 months

NPBurrows

Signed: N P Burrows
Title: Field Operations Manager

APPENDIX 7.3 BASEMENT IMPACT ASSESSMENT

APPENDIX 8.2 BASEMENT IMPACT ASSESSMENT

Dublin Central: Site 2

Basement Impact Assessment -

DC-WAT-2X-XX-RP-C-002017

September 2022

Waterman Structures Limited

Pickfords Wharf, Clink Street, London, SE1 9DG,

www.watermangroup.com

Client Name:	Dublin Central GP Ltd
Document Reference:	DC-WAT-2X-XX-RP-C-002017
Project Number:	STR15283

Quality Assurance – Approval Status

This document has been prepared and checked in accordance with
Waterman Group's IMS (BS EN ISO 9001: 2015, BS EN ISO 14001: 2015 and BS EN ISO 45001:2018)

Issue	Date	Prepared by	Checked by	Approved by
P01	September 22	Yan Geng	A Spence	C Beresford
PO2	May 2023	C Beresford/A Fasano	P Swift	H Blacker

Comments

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Comments

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Executive Summary

Overview

Dublin Central General Partnership Ltd (DCGP Ltd), has prepared a masterplan for the development of land in the area generally bounded by O'Connell Street Upper, Parnell Street, Moore Street and Henry Place. The masterplan is subdivided into a number of individual development sites each of which is the subject of a separate planning application.

This Basement Impact Assessment has been prepared consider the impact of the basement proposed in the redevelopment of Site 2 of the Dublin Central project.
This site, Site 2 extends from 43 O'Connell Street to the North, 58 O'Connell Street to the South and Moore Lane to the West and O'Connell Street Upper to the East.

The Site 2 works include the development of 2 new buildings facing onto O'Connell Street and extending West to Moore Lane above a new @4m deep single level basement. DCGP Ltd has also entered into a development agreement with Transport Infrastructure Ireland (TII) to incorporate a concrete box below the development basement to enable the future O'Connell Street Station which is part of the proposed Metrolink project. The Metrolink project planned by TII is the subject of a Railway Order which has been submitted by TII. The station box structure being provided by DCGP Ltd is enabling works only, but including this within the DCGP Ltd development requires careful consideration of the impact of this large and deep structure, the station box is @120m long, 27m wide and 25-30m deep and extends across a large area of the Site 2 plot.

This report provides assessment against the requirements of Appendix 9- Basement Development Guidance- of the Dublin City Development Plan 2022-28

The following evaluation of the impact of Site 2 construction works on adjacent buildings, protected structures and adjacent infrastructure assets, considers a bottom up construction methodology as set out in this report.

It should also be noted that the construction contract for the works will be awarded on a design and build basis and the main contractor's and their design team will be provided with copies of all relevant reports to enable them to further develop the detailed design and construction methodology..

The technical studies undertaken in preparing this report consider the proposed demolition works, basement excavations, and reconstruction of the new buildings proposed for the site.

The purpose of the report is to demonstrate that the works as designed and based upon the assumed construction methodology have taken account of the surroundings and does not have a significant impact on adjacent buildings and assets.

Conclusions

Buildings

The potential for damage due to ground movement during the demolition and construction process for the assessed protected and neighbouring structures remains within Category 0 **'Negligible'** to Category 1 **'Very Slight'** damage during all construction stages.

The structures considered within this study are representative of the buildings in the near vicinity and included 42 O'Connell Street and O'Connell Hall, 59 O'Connell Street (and the Reading Room) and the National Monument located at 14-17 Moore Street.

There are a number of retained facades on the site and these were not assessed as they are extremely close to the main excavation, however they are all within the control of the Site 2 construction team and will be monitored for movement against a trigger level criteria that will be established and agreed with the construction team.

The potential impacts of Site 2 works are in accordance with DCC Guidance, and therefore, can be considered as acceptable.

Luas

The predicted ground movements and the associated LUAS light rail track movements are considered to be moderately conservative, in view of the relatively cautious data selection and *greenfield* nature of the assessment undertaken.

The predicted results for the Luas light rail tracks do not show any onerous conditions for the assets and the calculated movements are below the limits proposed by the TII document - Code of engineering practice for works on, near, or adjacent the Luas light rail system. Therefore, the proposed Site 2 works do not highlight any concern to affect the day-to-day operations.

In view of the above findings, the risk of impact on the LUAS light railway associated with the proposed development construction, is considered to be low.

Sewer infrastructure

The impact on the Sewers in Moore Lane and O'Rahilly Parade are also generally within industry guidance levels with the exception of one small length of sewer in O'Rahilly Parade. This may require investigation to inspect the sewer and further consideration during the detailed design stage. However the analysis undertaken at this stage only shows a minor over stress which should not present a major difficulty. The main contractor will be reviewing the methodology and presenting further assessment in due course.

It is concluded that the sewers in proximity of the site will be subject to movements and strains within the allowable criteria (generally based on experience of similar projects) except for Sewer 5, for which the estimated tensile strain exceeds the allowable limit.

In view of the above, with the exception of Sewer 5, the risk to the utilities in proximity to the development, due to the ground movements induced by the proposed scheme construction, is considered to be low.

Monitoring

As the design progresses towards a tender and construction stage a number of neighbouring properties and assets including 42 and 59 O'Connell Street, the National Monument and the LUAS line track will be monitored for movement during the works. A remote monitoring system will be specified and installed allowing continuous live reporting. A method and approach for monitoring buildings and other asset will be developed by Waterman and DCGP Ltd team and agreed with the main contractor. This will include movement threshold limits based upon a "traffic light" red amber, green action system of control.

General

Further detailed design work will be required by the main contractor's team as their design and construction methodology is developed through the preconstruction and construction process .

This report will be included in the design and build contract documentation to inform the potential main contractor and their design team of the approach and solutions considered during the development of the planning and conceptual design stage of the project.

1. Introduction

1.1 Objectives

This Basement Impact Assessment has been prepared to consider the impact of the basement proposed in the redevelopment of Site 2 of the Dublin Central project. The document has been updated to respond to the request for further information received from Dublin City Council in December 2022.

This report provides assessment against the requirements of Appendix 9- Basement Development Guidance- of the Dublin City Development Plan 2022-28

A series of analyses have been undertaken based up the preferred construction methodology, the fundamental considerations being:

1. Impact of ground movement during excavation and construction.
2. The impact of temporary dewatering during the excavation of the basement areas.
3. The impact on ground water levels due to the scale of basement construction proposed (Barrier effect)

Ground movement and ground water flows have been assessed using the commercial software Oasys PDisp and XDisp, in parallel with PLAXIS modelling. The analyses evaluate the ground movements during excavation and due to changes in ground water levels. The output enables a consideration of the potential impact on adjacent structures owned by third parties including 59 O'Connell Street, The National Monument located at 14-17 Moore Street, protected structures owned by DCGP Ltd at 42 O'Connell Street which also includes O'Connell Hall, together with retained facades within Site 2.

In addition, we have also assessed the impact of the excavation and the effects on ground water levels on the LUAS line in O'Connell Street Upper and the local sewers located in Moore Lane and O'Rahilly Parade.

The analyses evaluate ground movements at three key stages of the proposed construction:

- Demolition works.
- Basement excavation, and
- Proposed building loading.

1.2 Site Location and Description

The Dublin Central project is an expansive (c.2.2 Ha) and complex regeneration project. It needs to be delivered in stages to overcome site and project constraints.

A site wide cumulative masterplan has been prepared by the Applicant to set out the overall development vision for the Dublin Central project. 'The Masterplan' area encompasses almost entirely three urban blocks. The area is bounded generally by O'Connell Street Upper and Henry Place to the east, Henry Street to the south, Moore Street to the west, and O'Rahilly Parade and Parnell Street to the north. Moore Lane extends south from Parnell Street through the centre of the masterplan area, as far as its junction with Henry Place.

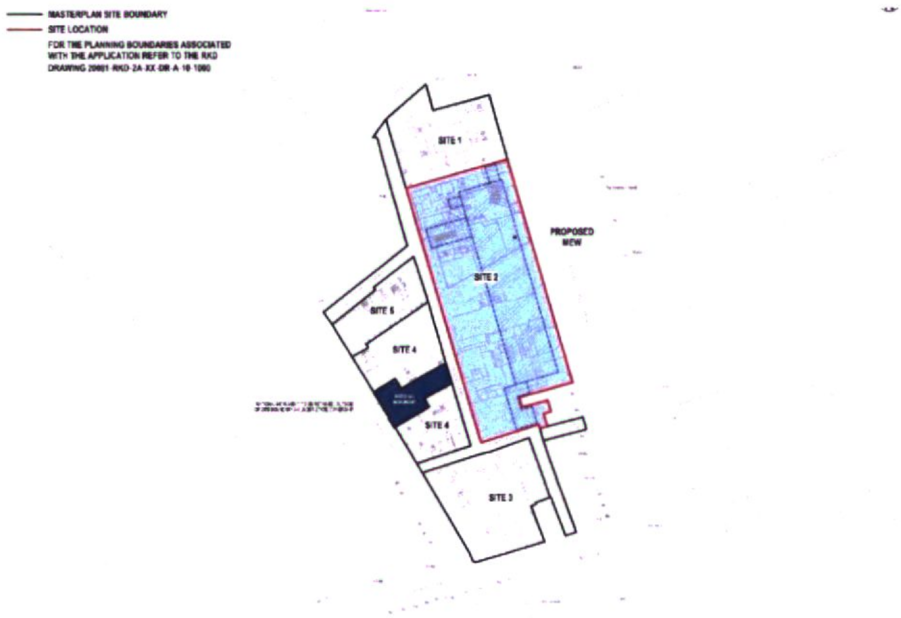

Figure 1. Site 2 Location Plan

'The Masterplan' area includes structures of heritage significance that will be retained; refer to section 2.2 for details of buildings retained within Site 2.

Nos.14 -17 Moore Street are under the ownership of the Dept. of Housing, Local Government and Heritage and are not part of the Masterplan area. The buildings have been designated National Monument status and are subject to a preservation order.

The Masterplan area has been divided into five identifiable sites for the purpose of making planning applications. The adopted site numbering is shown in Figure 1 also showing the location of each site within the Masterplan. For the planning boundaries associated with the application refer to the RKD drawing 20081-RKD-2A-ZZ-DR-A-10-1000. Site 2 is also subdivided into Block 2AB and Block 2C to enable reference to the 2 buildings that sit above a combined basement and the proposed MetroLink Enabling works. Figure 3 shows the temporary use of Site 5 as a materials and lorry marshalling area.,

'The Masterplan' (March 2021) proposes 2 independent buildings above ground on the Site 2 development. Block 2AB provides ground floor retail and café / restaurant uses and offices above and ranges in height from 2 to 7 storeys over new single storey combined basement which also extends beneath with Block 2C. A new street is also provided between the 2 buildings connecting O'Connell Street Upper and Moore Lane. Block 2C provides the same ground floor retail and café / restaurant uses with offices above ranging in height from 5 to 8 storeys over the combined basement beneath Block 2AB.

Both Sites share a single storey basement to include a car park and plant.

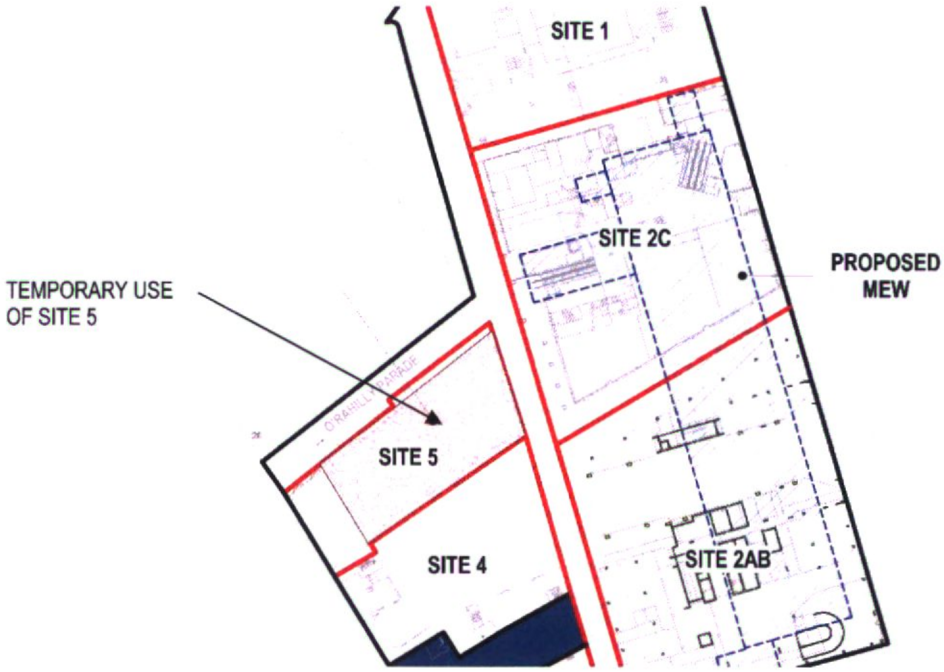

Figure 2 Temporary vehicle marshalling area.

The land to the rear of site 5 is to be utilised as a temporary vehicle marshalling area during construction of Site 2 due to the restricted access and width of Moore Lane.

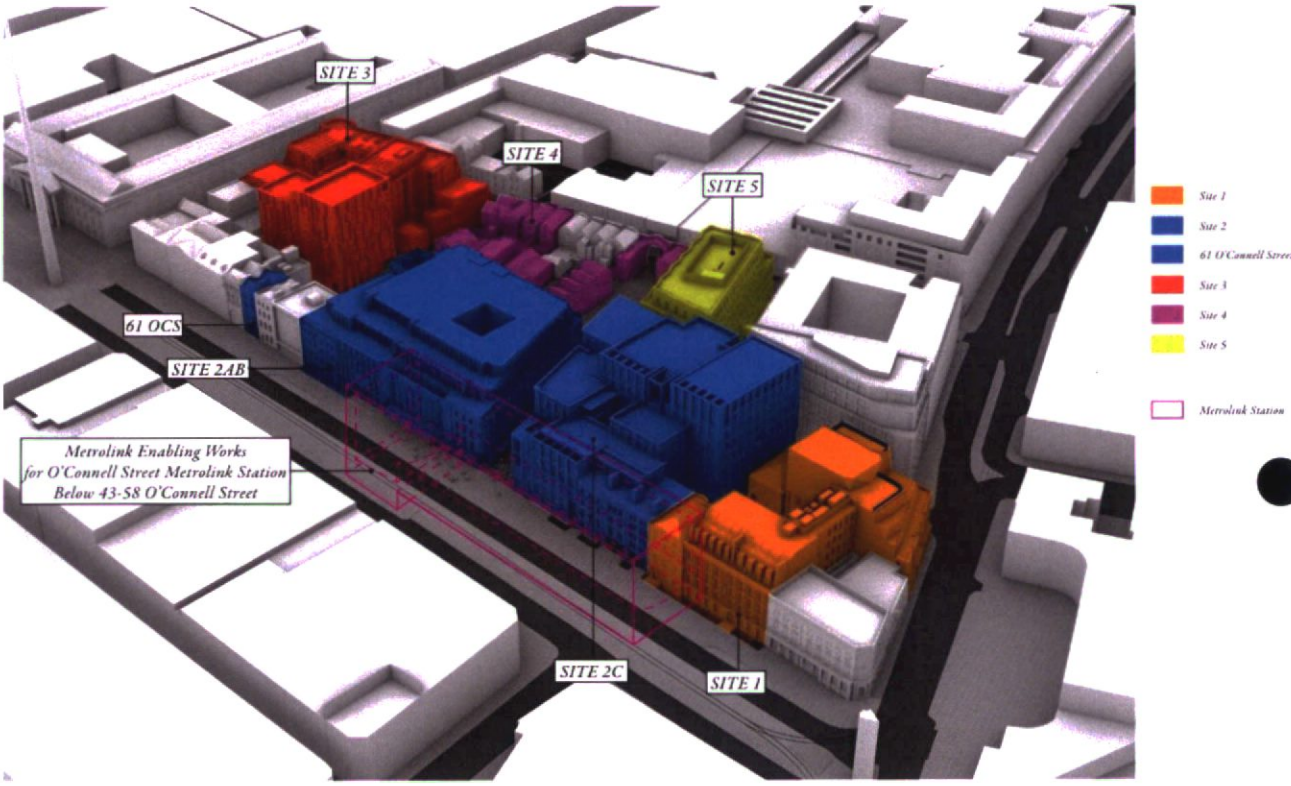

Figure 3. Masterplan

1.3 MetroLink Enabling Works

The National Transport Authority (NTA) and Transport Infrastructure Ireland (TII) approached the Applicant in 2018 with a view to locating a future MetroLink Station serving O'Connell Street within the Dublin Central site, in an effort to avoid locating the Station within the central median of O'Connell Street. TII is in the process of finalising the design of the MetroLink project. TII was originally expected to make an Application for a Railway Order for the MetroLink project, including the O'Connell Street Station, in Q3 2022. This was subsequently submitted in early 2023.

As part of the Dublin Central development there is a requirement to incorporate MetroLink Enabling Works (MEW) within the design and construction of Site 2. Through consultation with Transport Infrastructure Ireland (TII) and based upon the current TII preliminary design carried out by Jacobs Idom a structural "box" beneath the ground floor level has been incorporated in the Site 2 basement design. The structural box is to accommodate the independent construction and operation of the planned O'Connell Street MetroLink Station which is being designed by Transport Infrastructure Ireland. This includes provision of co-ordinated voids to accommodate station entrances, ventilation, and fire escape shafts through this part of the Dublin Central proposed development. These ensure that the proposed Dublin Central development is structurally independent of, and not prejudicial to, the MetroLink project.

The MetroLink project will be the subject of a separate application for approval to be made by Transport Infrastructure Ireland. MetroLink Enabling Works (MEW) are however proposed within the

Site 2 application, to be undertaken by the Applicant, with the actual station and railway works to be undertaken separately by TII at a later date.

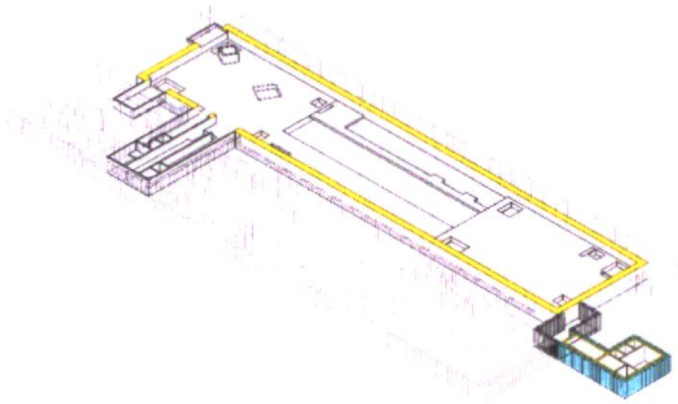

Figure 4. Section Through MEW Construction (Concourse Level)

The provision of the MetroLink O'Connell Street Station and its associated tunnel works would be completed by the NTA/TII once ready to do so and subject to the required consents being in place. It is envisaged that the MEW works would be completed in advance of the NTA/TII tunnel boring machines reaching the area.

2. Existing Site Assets

2.1 Masterplan and Context

The location of protected and retained structures across the site is shown in Figure 5.

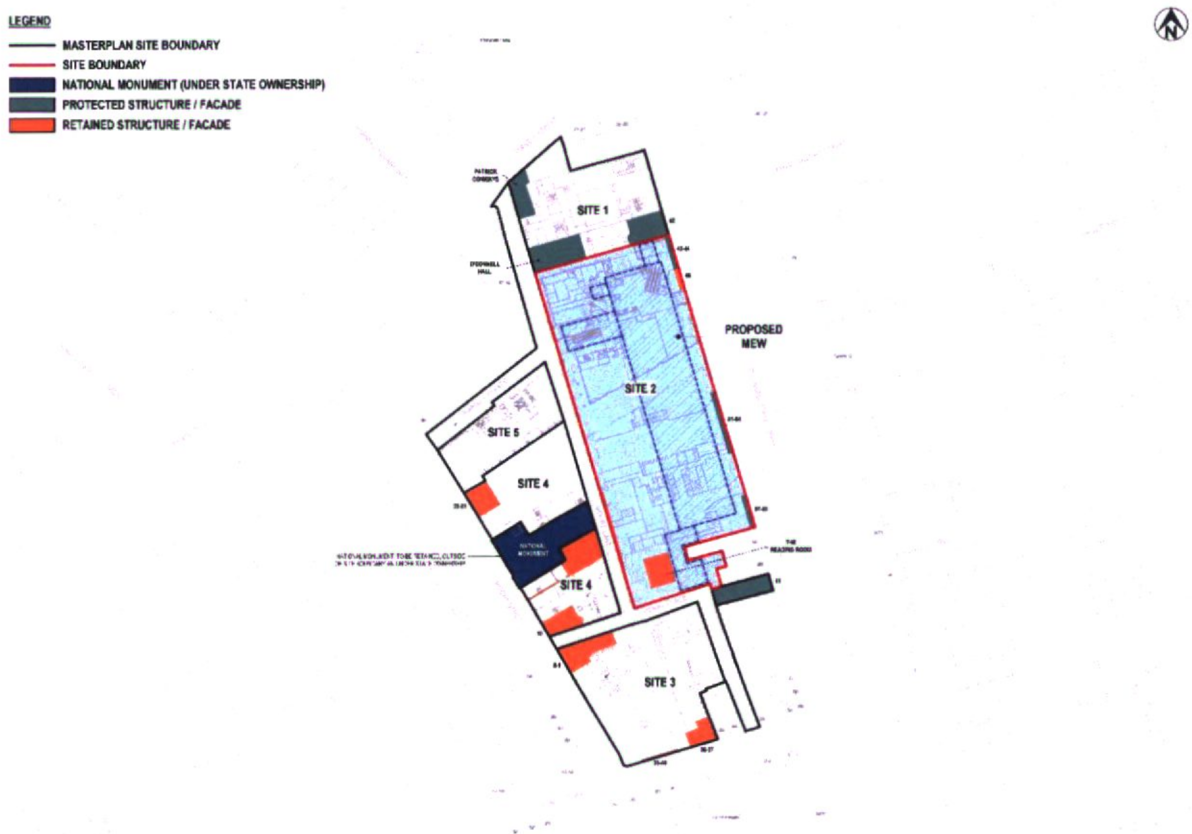

Figure 5 *Overview of protected structures and retained facades*

2.2 Protected Structures and Retained Façades

The Dublin Central Masterplan area includes structures of heritage significance that will be retained, including:

Protected structures:

- No. 42 O'Connell Street Upper and O'Connell Hall
- Nos.43 – 44 O'Connell Street Upper*
- Nos. 52 – 54 O'Connell Street Upper* (former Carlton Cinema)
- Nos. 57 – 58 O'Connell Street Upper*
- No. 61 O'Connell Street*

(*) means that only upper floor façade is listed as protected.

Non-Protected structures:

- 'The Reading Room' to rear of No. 59 – 60 O'Connell Street Upper
- Nos. 36 – 37 Henry Street
- Nos. 39 – 40 Henry Street (façades only)
- Nos. 8 – 9 Moore Street
- Nos. 11 – 13 Henry Place
- No. 5 Moore Lane (façade only)
- Nos. 6 – 7 Moore Lane
- No. 10 Moore Street
- Nos. 20 – 21 Moore Street

The following properties are not within The Dublin Central Masterplan area:

- Nos. 37 – 39 and Nos. 62 – 69 O'Connell Street Upper.
- Nos. 59 – 60 O'Connell Street Upper – specifically the buildings fronting O'Connell Street are excluded. Certain lands to the rear of Nos. 59 – 60 O'Connell Street Upper are included in The Dublin Central Masterplan area.
- Nos. 31 – 35 Henry Street
- Nos. 1 – 2 Henry Place.
- Nos. 14 – 17 Moore Street (The National Monument)
- Nos. 73 – 75 Parnell Street.

2.3 Other local assets

The LUAS light railway operates in the central reservation of O'Connell Street.

There is also infrastructure including 810x510mm brick and 300mm Vitreous Clay sewers in close proximity of Site 2 in Moore Lane and O'Rahilly Parade and both are also assessed in this report.

Figure 6 Sewers in Moore Lane and O'Rahilly Parade

The scale and nature of the redevelopment of Site 2 requires a significant amount of demolition between 43 and 58 O'Connell Street. The wider masterplan also involves the reconstruction of Sites 1,3, 4 and 5.

Therefore, for the purposes of assessing the impact of Site 2 basement works the following structures and infrastructure assets have been considered.

1. The National Monument at 14-17 Moore Street
2. 59 O'Connell Street including the Reading Room at the rear of the plot.
3. 42 O'Connell Street and O'Connell Hall
4. The Luas light railway
5. The various sewers in Moore Lane

These are the most sensitive and adjacent structures in the near vicinity of Site 2 and should be a fair and reasonable representative sample upon which to assess the impact of the works.

The report has not assessed the impact on the retained facades within the Site 2 area. These are generally within 5-10m of the excavation for the station box and it is accepted that they will be subject to some ground movement impact.

The close proximity to the station box excavation is an accepted risk due to the alternative to reposition the station box further to the West. This would however have increased the risk of ground movement impact to the National Monument.

Under the circumstances the National Monument was considered to be a higher priority as the retained facades can be monitored and managed during demolition and reconstruction by the DCGP Ltd design and construction team.

They will be included within the sensitive building movement monitoring and as they are to be incorporated into the completed project, they will be sensitively repaired and restored as the work progresses.

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3. Topographic Survey of Existing Buildings

The existing Site 2 plot has been surveyed by Murphy Surveys, the existing site survey plan at ground floor and basement are shown in Figures 7 and 8 below.

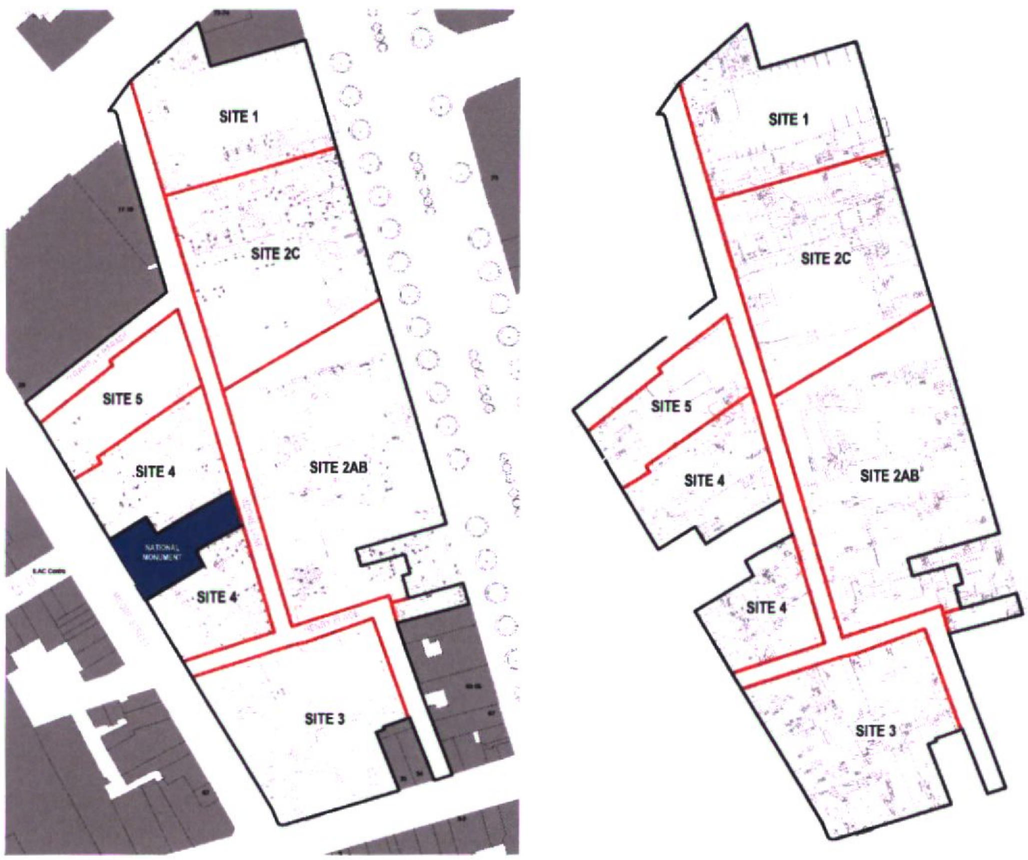

Figure 7 Existing Ground Floor Context Plan and overlay on Murphy Survey plan.

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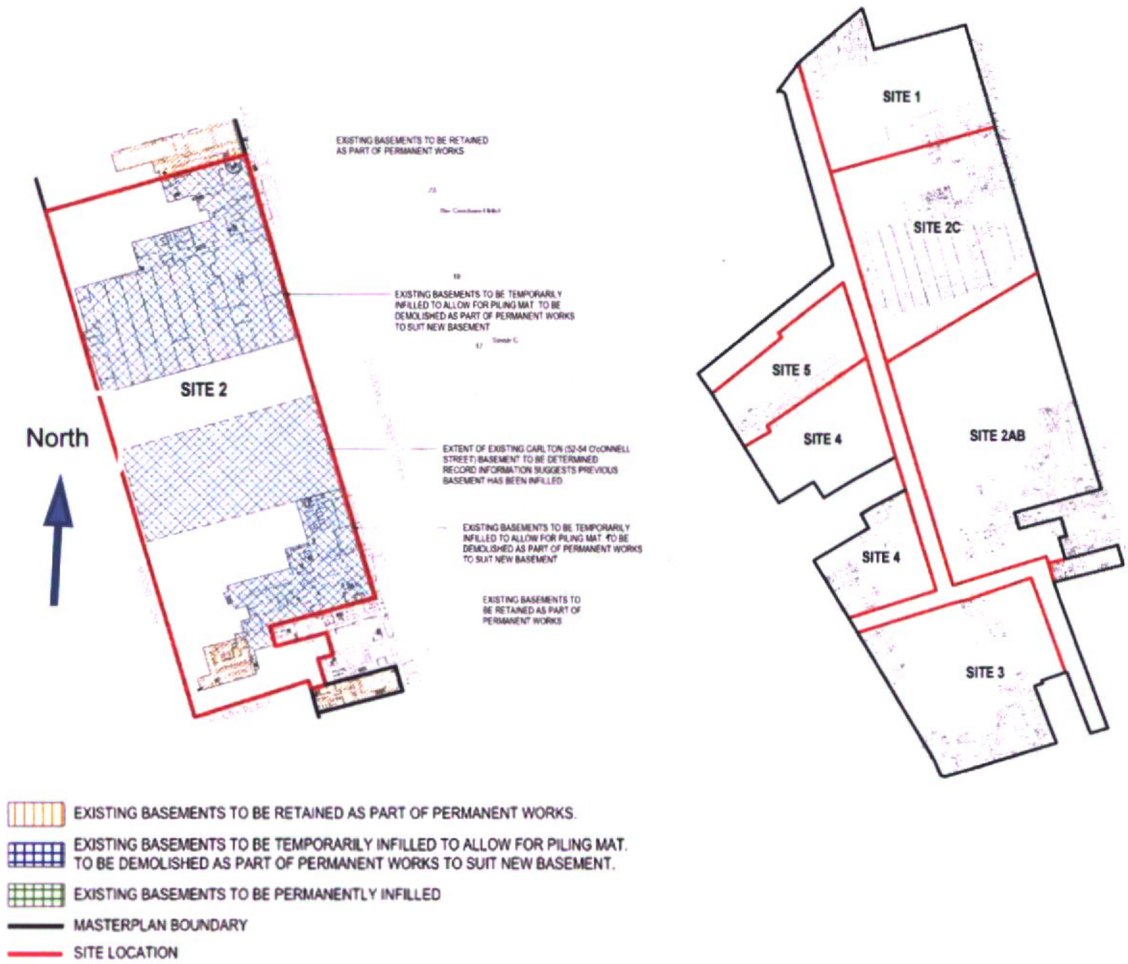

Figure 8 Basement Context Plan and overlay on Murphy survey plan.

4. Proposed Ground Floor, Basement Layout and TII Station Box plans

The following figures show the proposed structure of the ground floor and basement of the Site 2 development and plans of each level of the proposed station box.

A combination of embedded secant or contiguous piled retaining walls and diaphragm walls are planned in order to minimise the volume of excavation to form the basement level. These retaining structures will therefore support the earth pressures during excavation and construction.

Piled and diaphragm walls will provide an inherently stiff wall when propped with a robust temporary works propping scheme specifically designed to suit the excavation and construction methodology and sequence. The final design of the walls and the back propping will be provided by the main contractor/specialist sub-contractors. These walls will also provide a cut off/ barrier to ground water and will enable the excavation of the site in controlled conditions. The cut off wall will also reduce the loss of fine material from behind the wall and also help to limit ground movement that may otherwise impact on adjacent buildings and infrastructure.

The piled wall may in places also provide direct support for the superstructure, with the capping beam distributing substantial vertical loads on to the embedded retaining wall and using the vertical load capacity of the wall.

The concept design assumes the secant wall piles to be 600 / 750mm diameter, constructed with a CFA rig.

The Dublin Central oversite development and the Station box structure have been designed to be structurally independent which is desirable from an ownership perspective. \neither reqiring each other for lateral support or load bearing capacity.

For the purposes of this study the MEW construction has been considered as a bottom-up construction where the excavation will be advanced down to the lowest level. Horizontal props will be installed successively as construction progresses downwards. Once bottomed out the new lowest level slab will be cast, and work will proceed upwards with the temporary props being removed once the concrete has reached the desired strength. This will continue until the basement MEW works are complete. The propping is to be designed by the MEW contractor. The design will be influenced by the ground movement predictions and may be required to incorporate prestressing jacking to minimise lateral ground movement during the excavation and construction process.

The section drawing show the Site 2 basement and the station box in context.

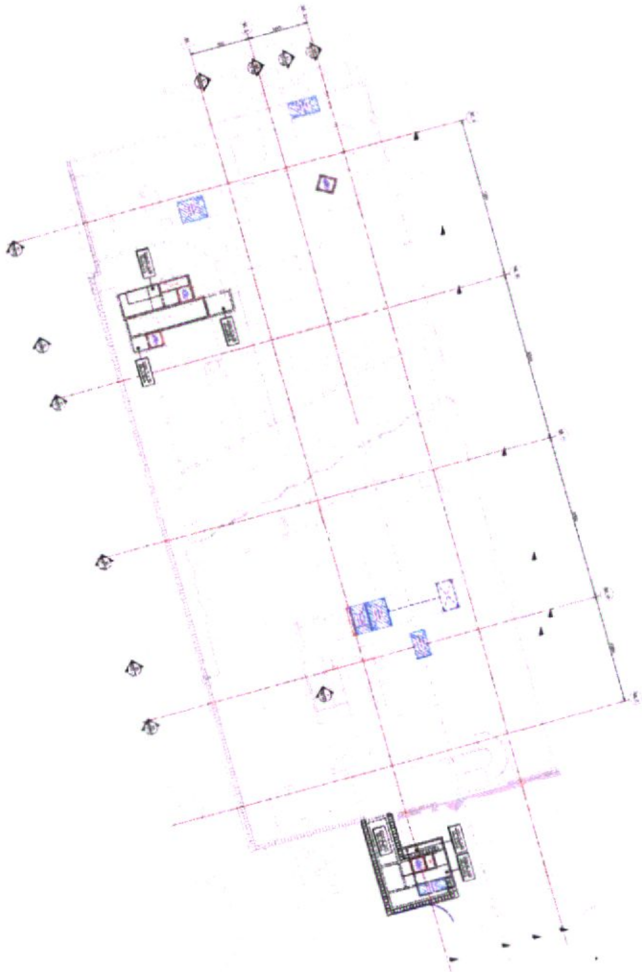

Figure 9 Proposed Site 2 Ground Floor Plan

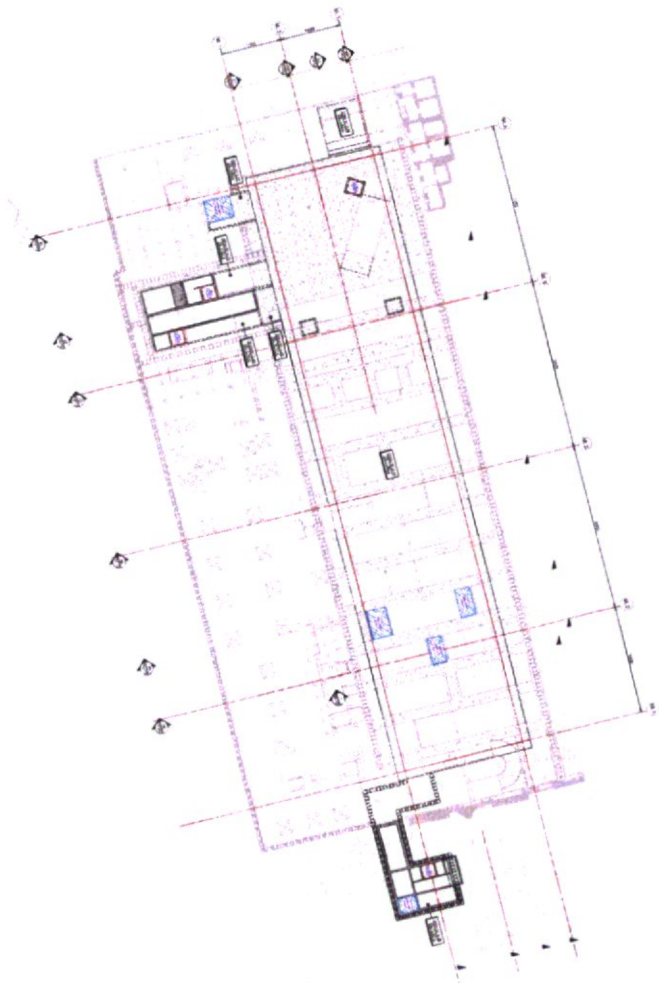

Figure 10 Proposed Site 2 Basement Plan

The following figures 9-14 show the Metrolink Station box plans.

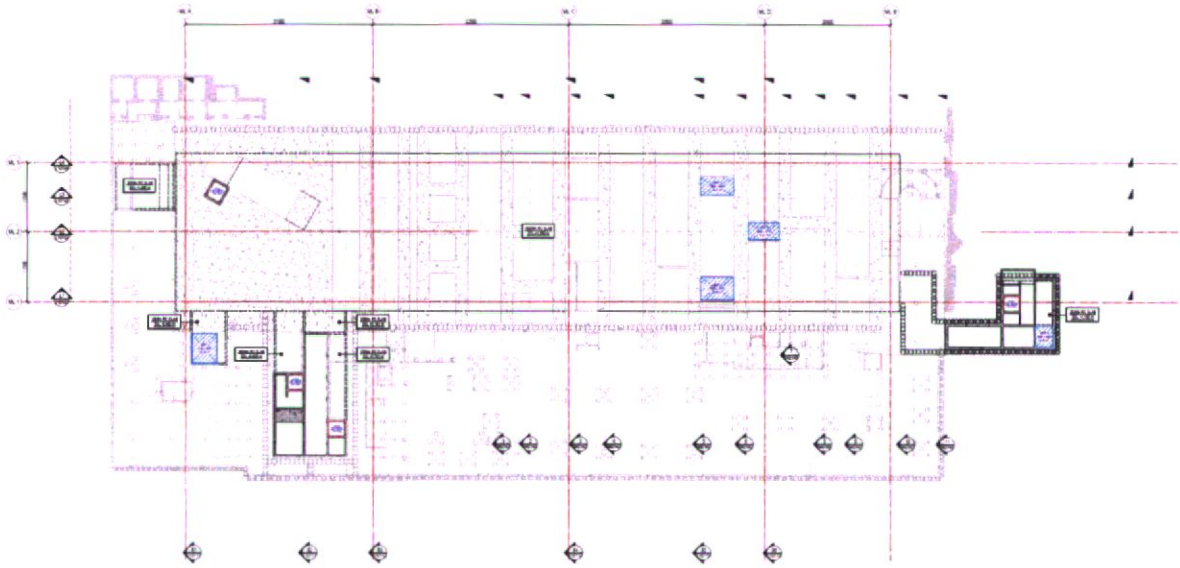

Figure 11 Roof slab over station box

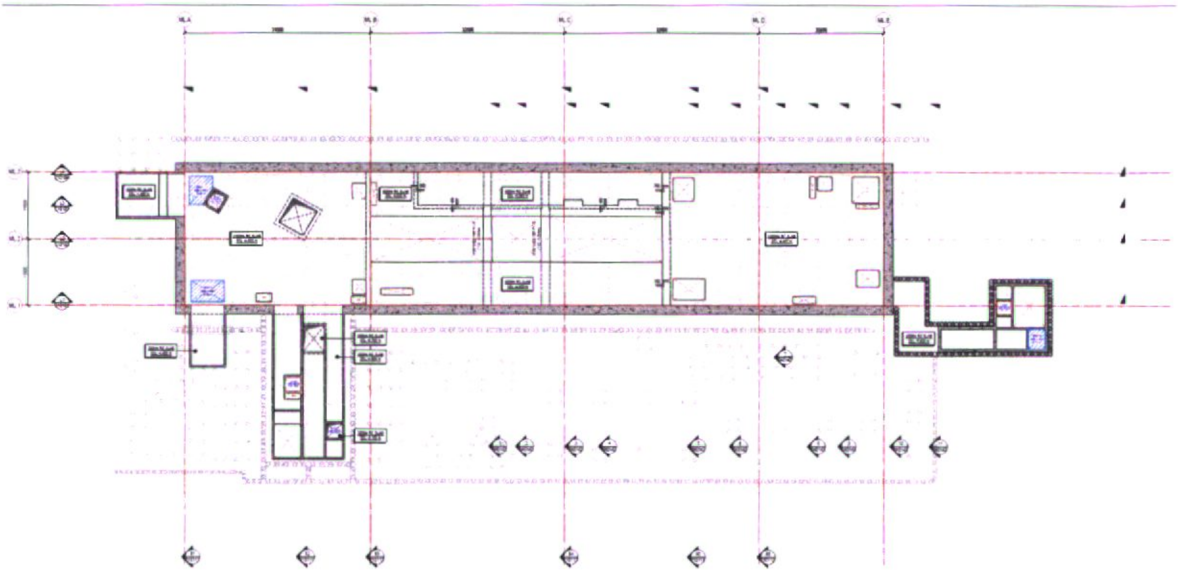

Figure 12 Concourse level slab station box

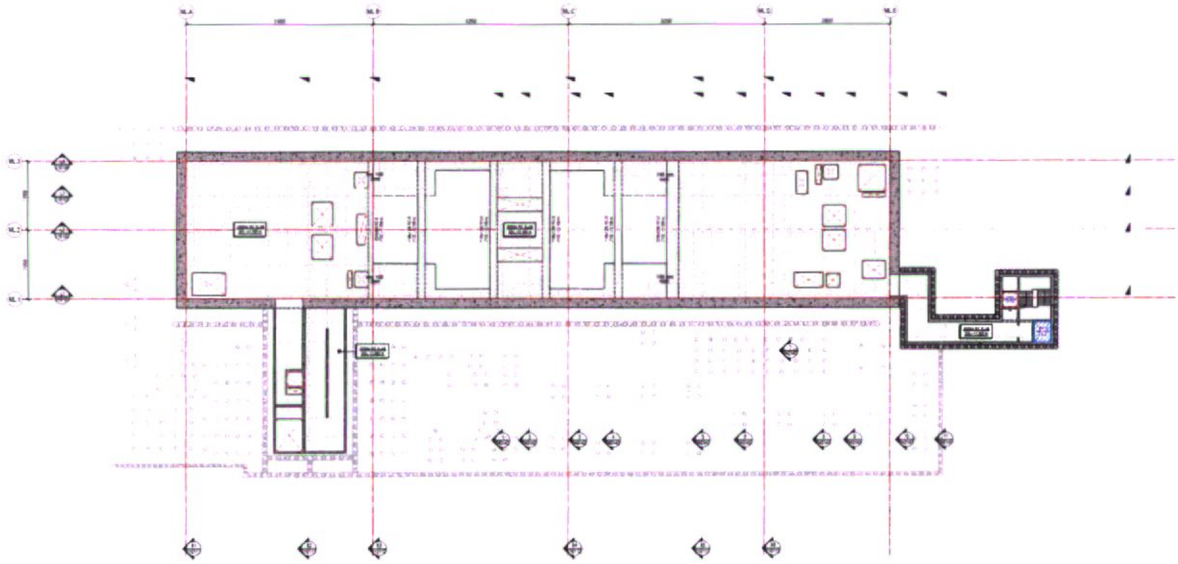

Figure 13Mezzanine level slab station box

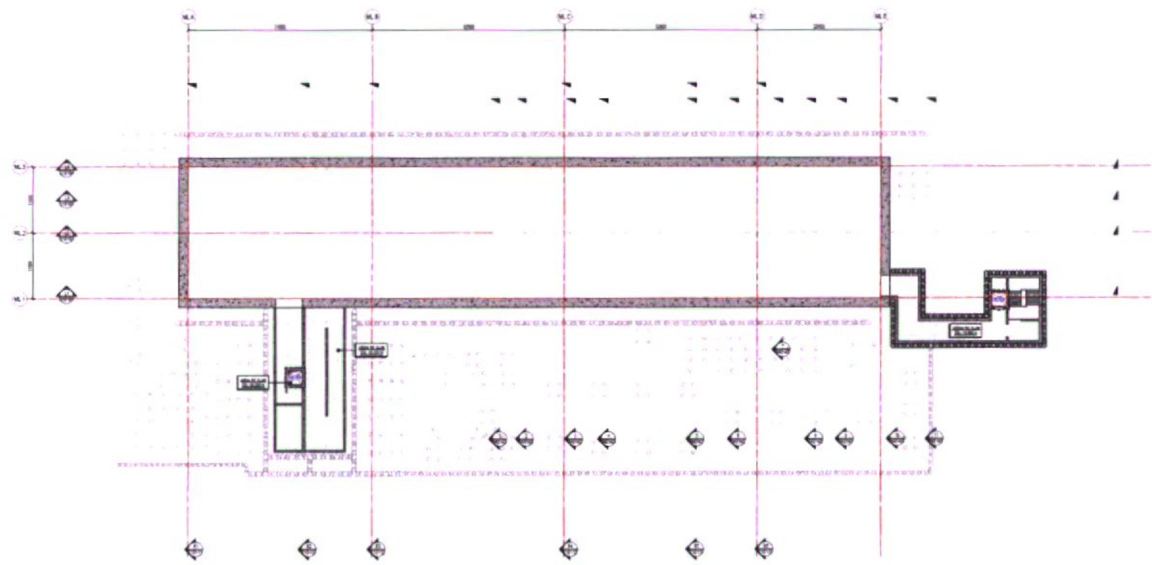

Figure 14 Platform level station box

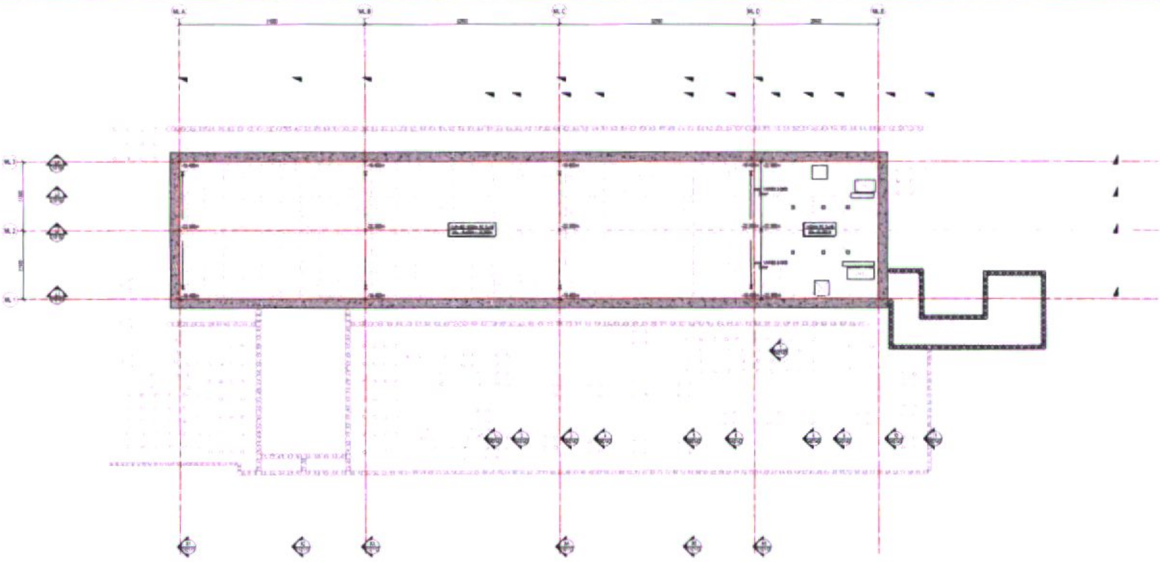

Figure 15 Undertrack level slab station box

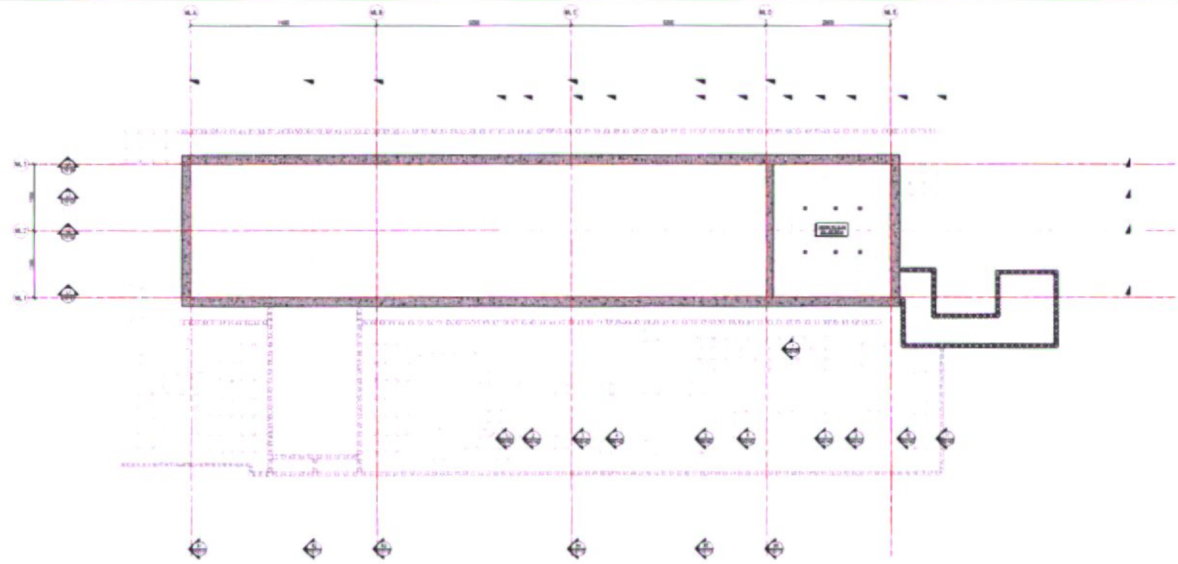

Figure 16 Local plant room slab station box

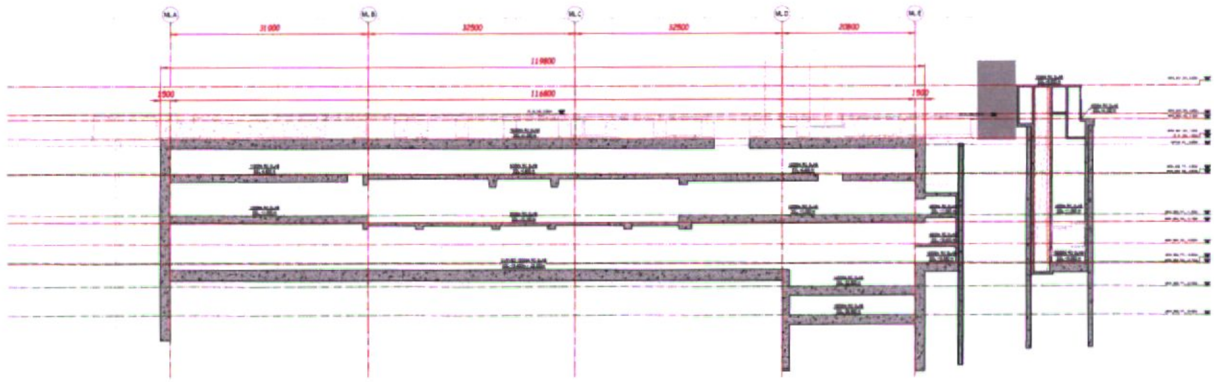

Figure 17 Longitudinal section 1 station box

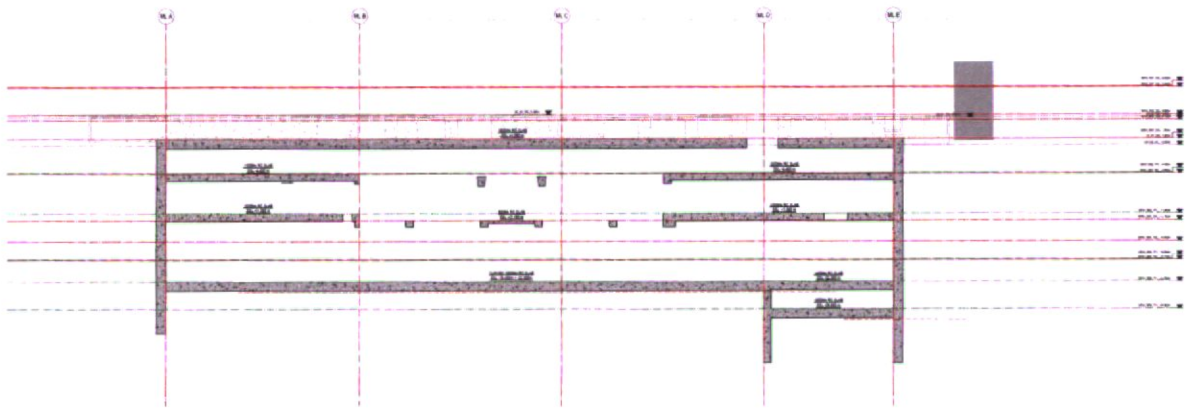

Figure 18 Longitudinal section 2 station box

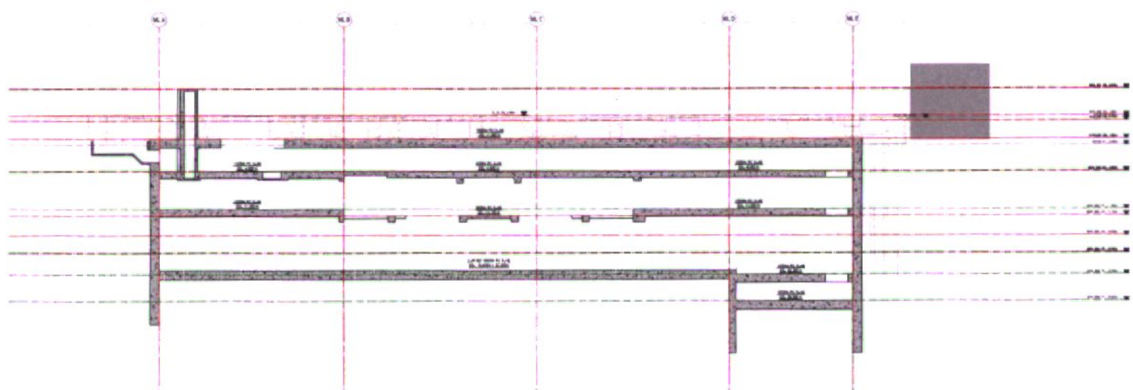

Figure 19 Longitudinal section 3 station box

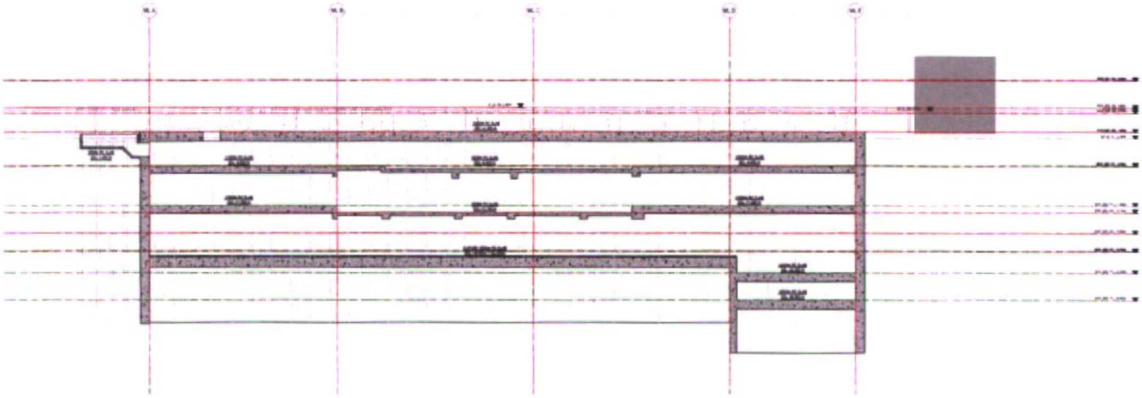

Figure 20 Longitudinal section 4 station box

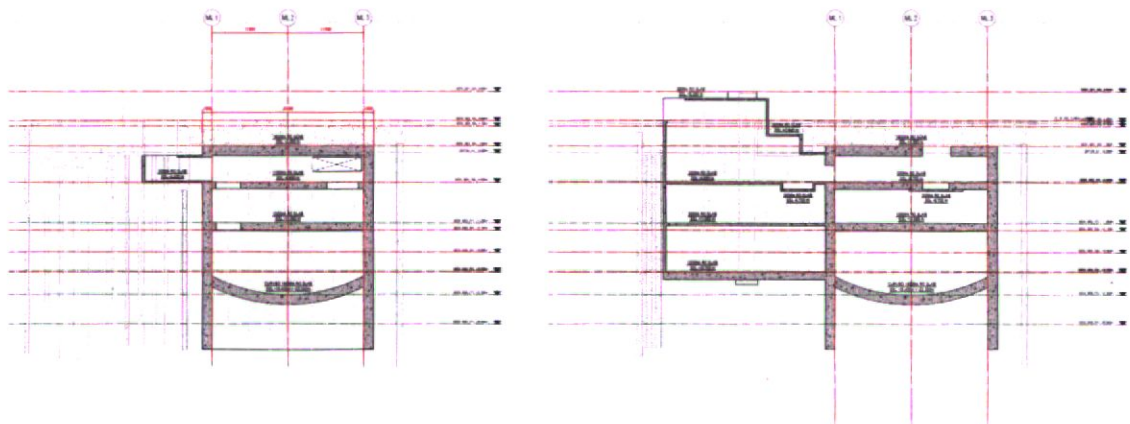

Figure 21 Cross Sections 1 and 2 station box

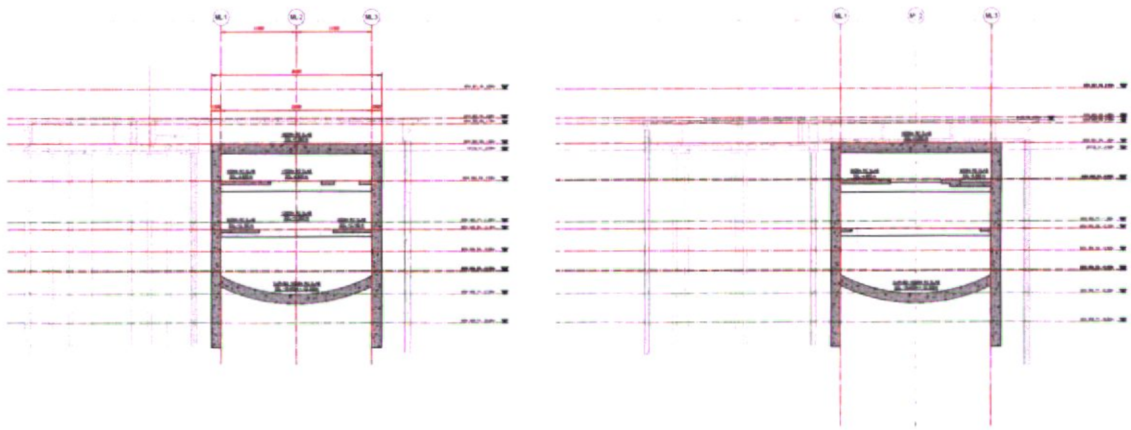

Figure 22 Cross sections 3 and 4 station box

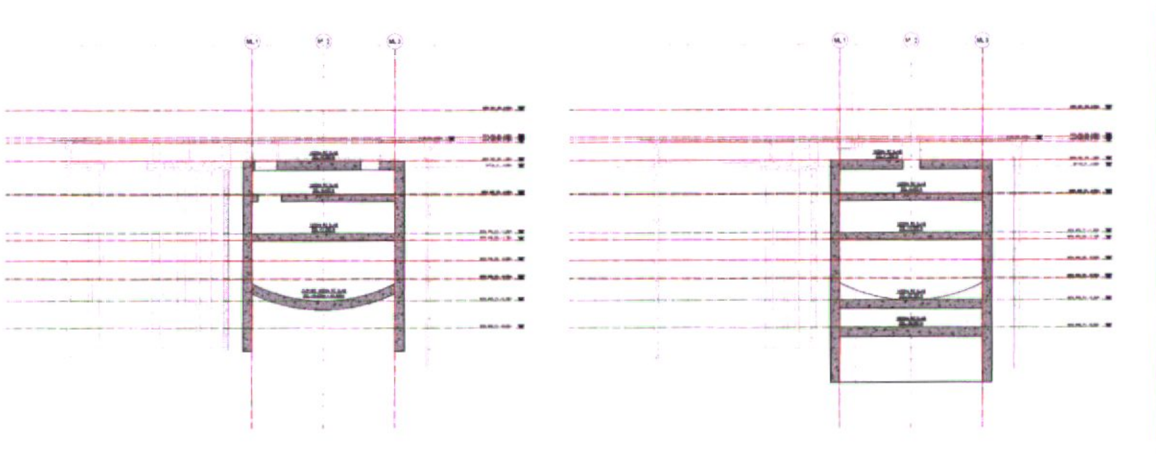

Figure 23 Cross sections 5 and 6 station box

4.1 Construction sequence

A construction phasing strategy envisages future build out from south to north, progressing generally from Henry Street towards Parnell Street.

The construction sequence to deliver Site 2 has to take account of the MEW requiring consideration of the excavation to enable construction of the basement and Station structural box.

The proposed construction phasing for the MEW and Site 2 can be found in Appendix C.

The MEW construction has been considered as a bottom-up construction where the excavation will be advanced down to the lowest level with the structure then being constructed from this bottom level. In the permanent condition the reinforced concrete slabs will act as permanent props between the diaphragm walls to resist lateral pressures. In the temporary condition horizontal props will be installed successively as excavation progresses downwards.

The diaphragm walls will be designed to minimise ground water from entering the area to be excavated but there is still potential for ground water to enter by passing beneath the diaphragm walls or by percolating up from the base of the excavation. During construction of the diaphragm walls or as the excavation to full depth is undertaken some pressure grouting of the soils and rock may be required.

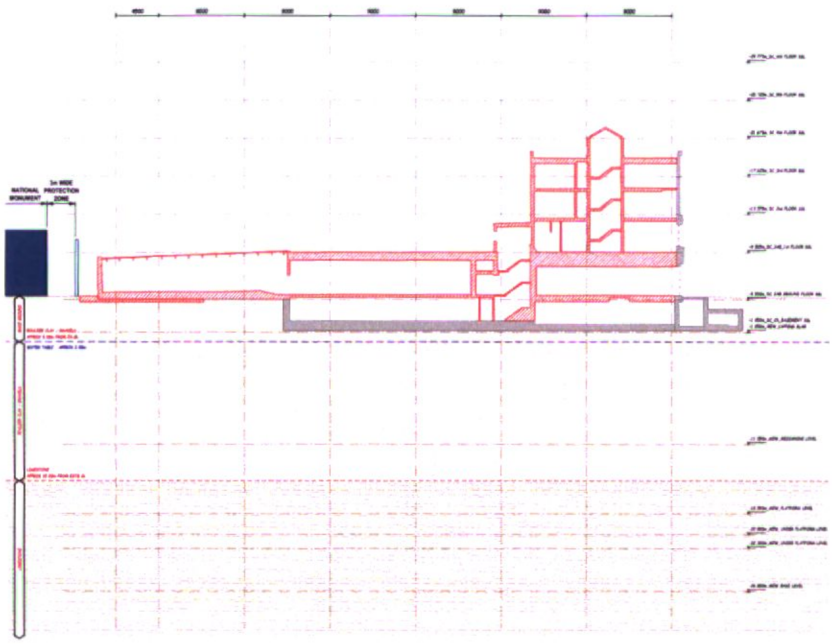

Figure 24 Phase 1 - Preparatory work and demolition including temp support to retained facades.

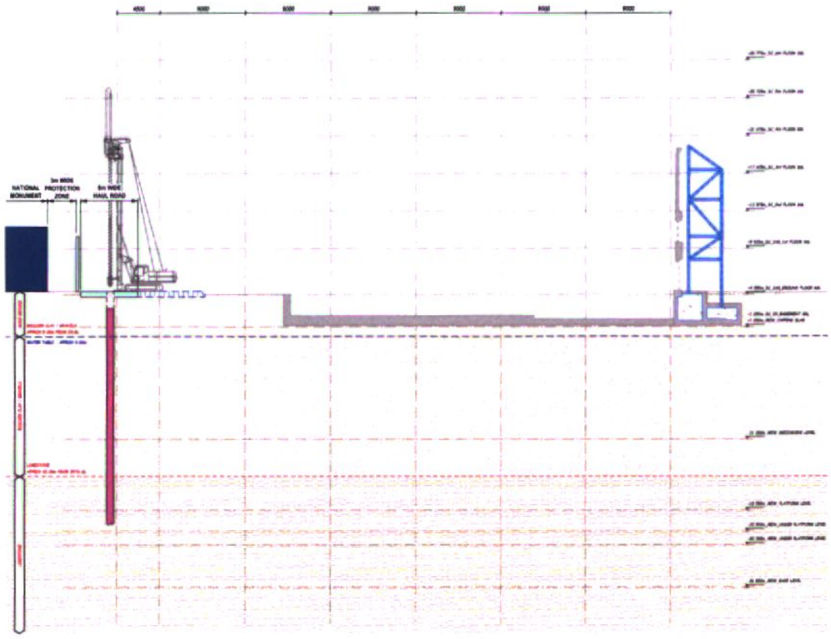

Figure 25 Phase 2 - Place Piling Mat to enable access for secant piling.

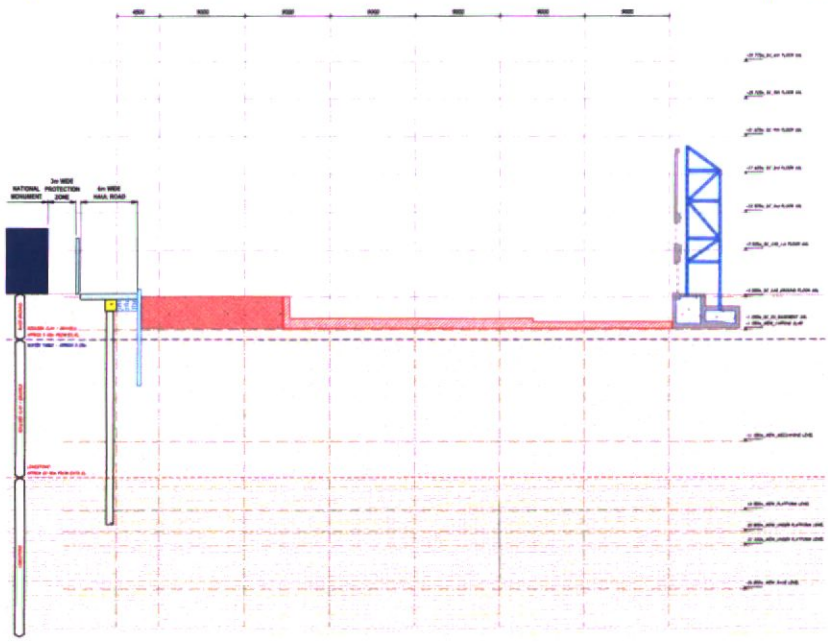

Figure 26 Phase 2 - Continue piling matt and grub up and remove old basement and foundations.

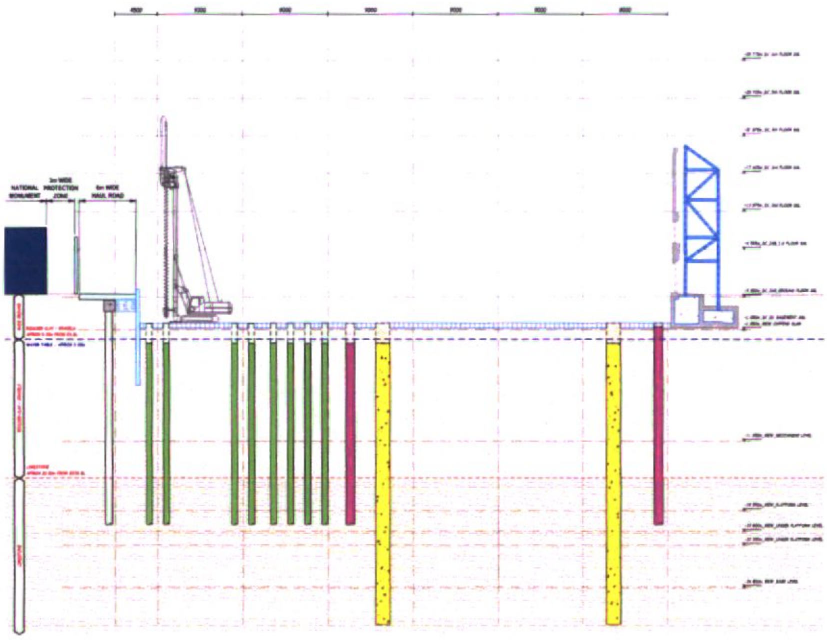

Figure 27 Phase 4 – Construct Diaphragm Walls to MEW and also continue oversite development foundation piling.

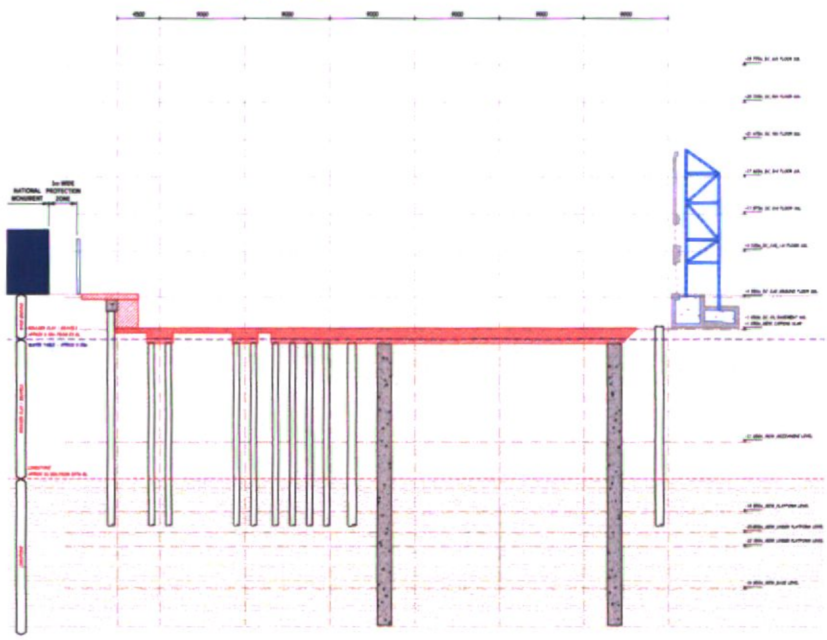

Figure 28 Phase 5 – Excavate to enable pile caps and expose top of Diaphragm walls.

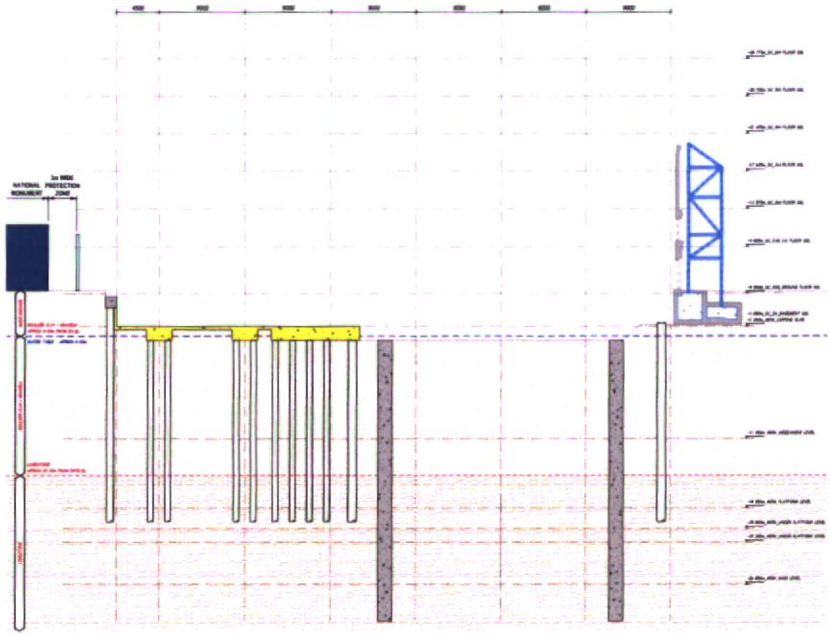

Figure 29 Phase 6 – Construct pile caps and crane bases

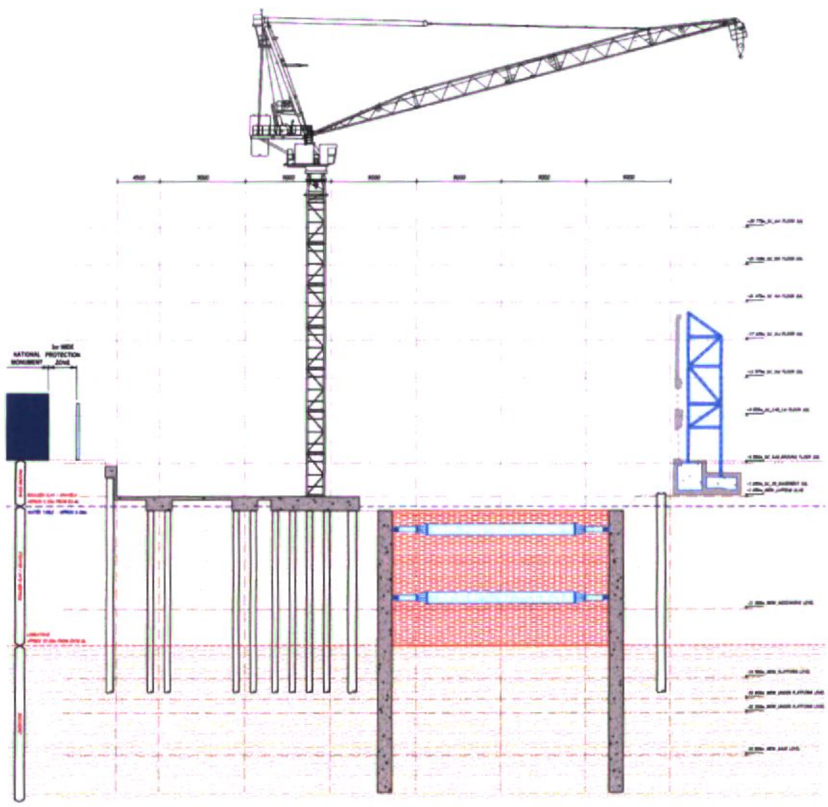

Figure 30 Phase 7 - Erect Tower cranes and commence excavation for MEW introducing back

propping as required.

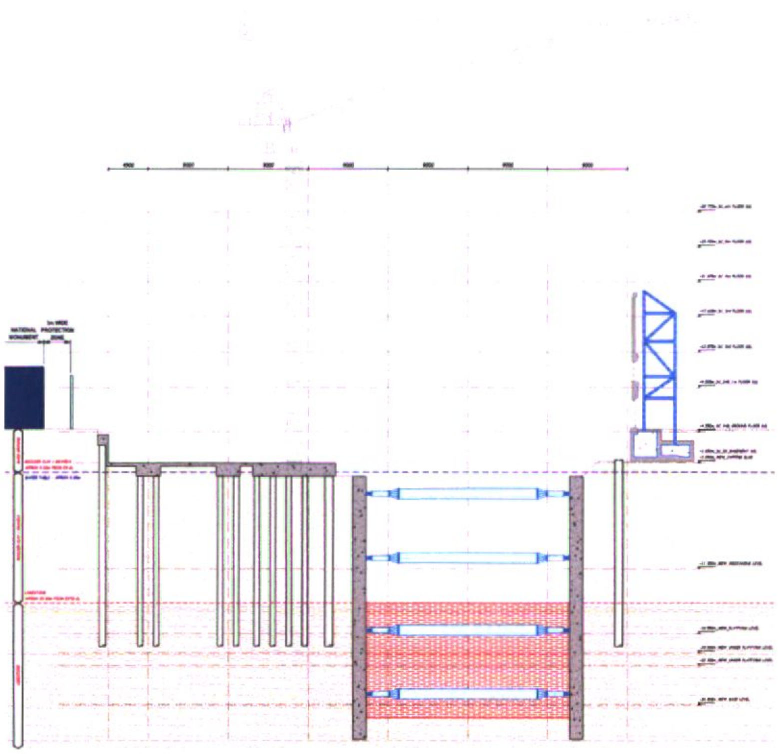

Figure 31 Phase 8 - Continue MEW excavation to base of MEW box.

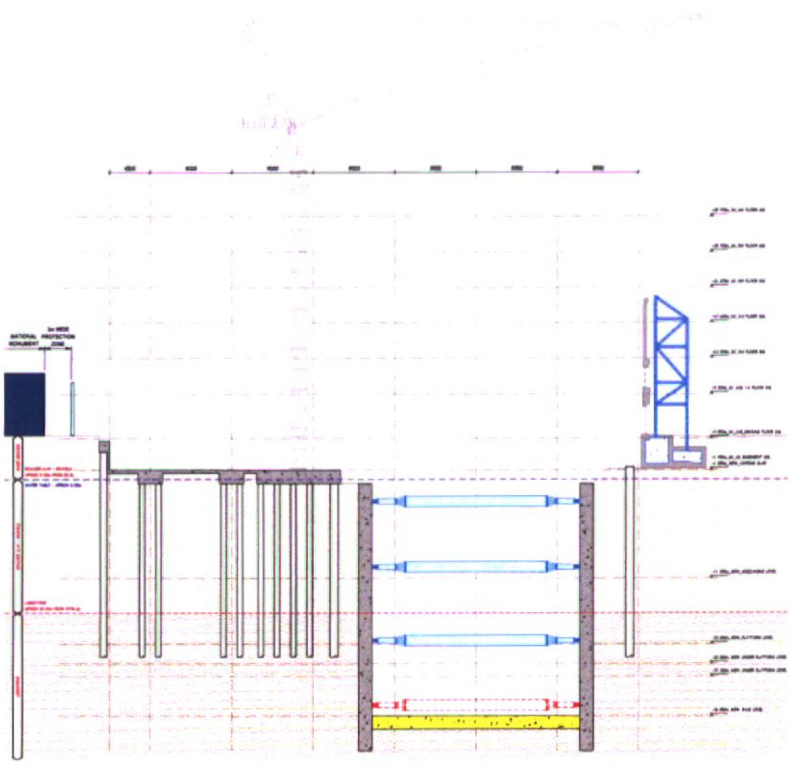

Figure 32 Phase 9 - Construct base of pump chamber and begin removing temp props.

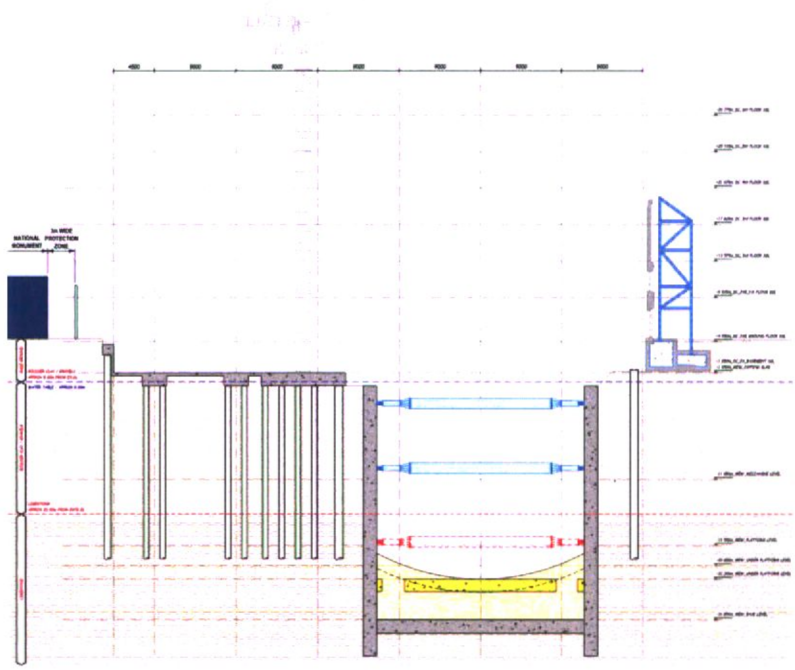

Figure 33 Phase 10 - Form base of main station box and remove lower-level props.

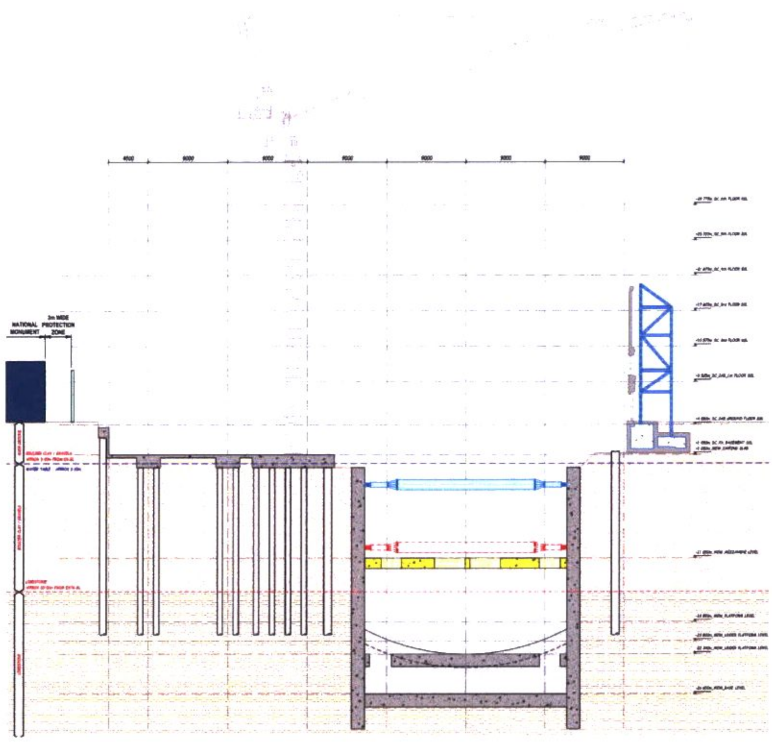

Figure 34 Phase 11 - Continue construction of internal slabs providing permanent support to diaphragm walls.

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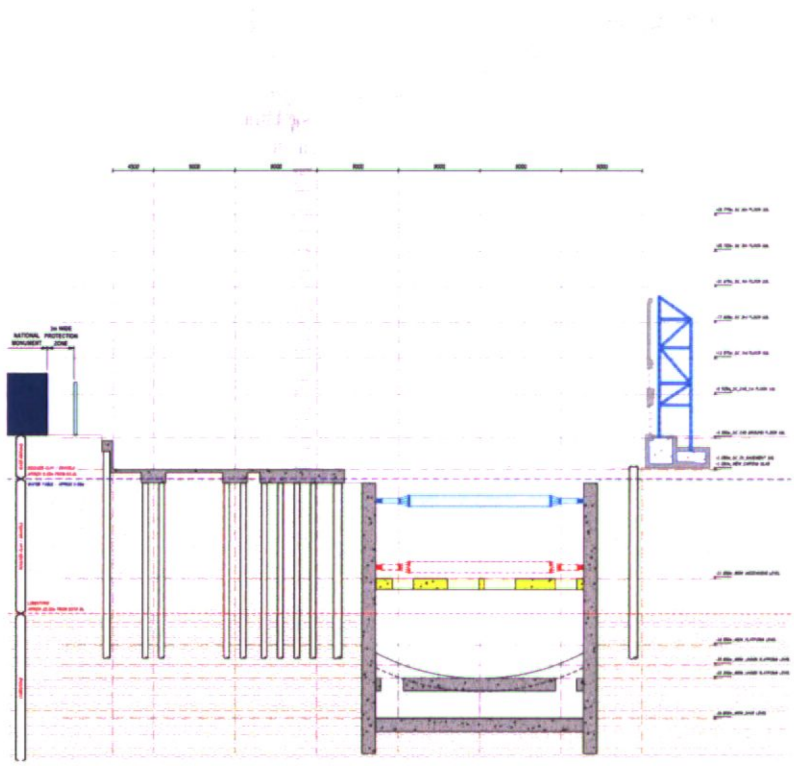

Figure 35 Phase 12 - Internal slabs continue to top.

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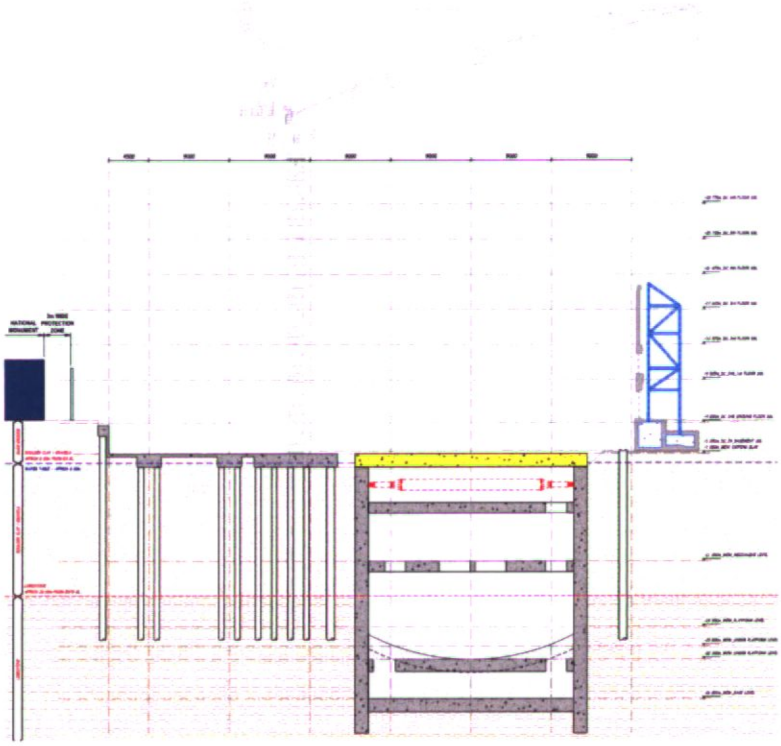

Figure 36 Phase 13 - Place top slab and remove final internal props.

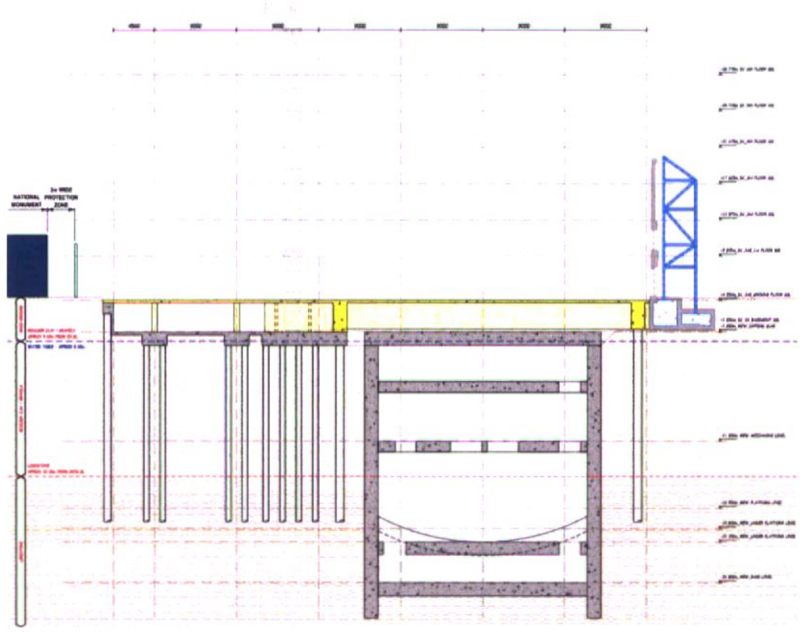

Figure 37 Phase 14 - Construct independent transfer structure above MEW box

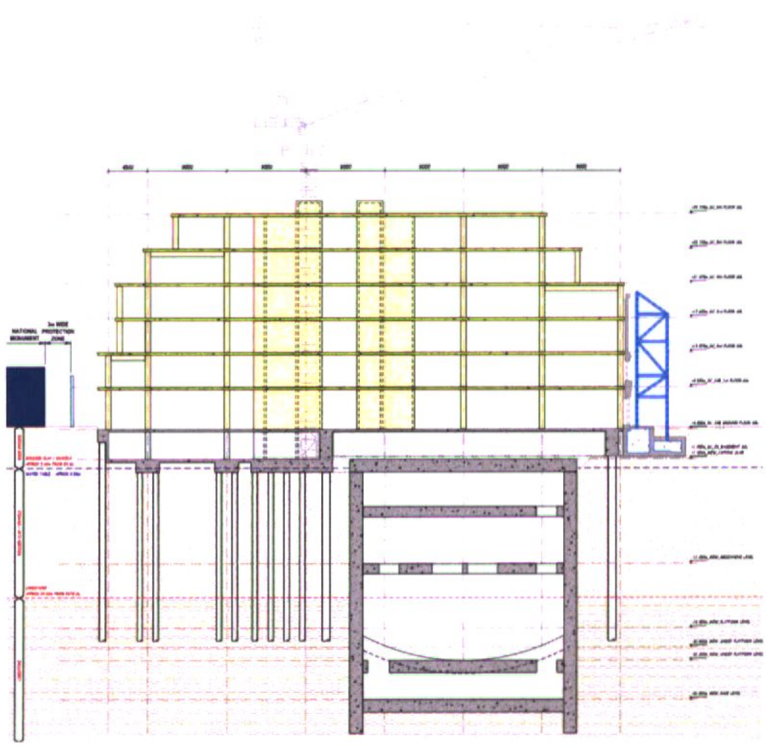

Figure 38 Phase 15 - Proceed with oversite development.

Further details of the approach are provided in the Subterranean Method Statement produced by Waterman Report ref DC-WAT-2X-XX-RP-C-002009 September 2022.

Waterman has also prepared an Outline Construction Management Plan- Site 2 ref. DC-WAT-2X-XX-RP-C-001012 April 2022.

The Preliminary Outline Construction Management Plan will be updated as the design progresses and will be made available to the main contractor. The main contractor will be required to submit method statements and to secure all necessary consents and approvals for all activities critical to the safety of all surrounding property and public highway.

The protected structures and other non-protected structures to be retained as part of the development will be monitored as previously described and as noted in the Preliminary Construction Management Plan.

The use of written method statements and technical submissions and approvals will mitigate the risks as a result of the subterranean construction work.

Monitoring of the retained facades and adjacent structures at 59 O'Connell Street, 42 O'Connell Street and the National Monument at 14-17 Moore Street will be required. The contract documentation to be issued with the design and build tender will set out the requirements for live monitoring.

5. Ground Conditions

5.1 Site Investigations

The Geological Society of Ireland (GSI) geological maps and previous ground investigations completed on-site indicates that the Site is underlain by superficial deposits comprising of Alluvium and Till and bedrock geology comprising Lucan Formation.

A summary of the geological strata encountered from Historical site investigations carried out on 2009 and subsequent investigations by TII is included in Table 1DCGP Ltd has utilised reports that were prepared by the previous building owners Charter Land that provide valuable information for the planning stage design. In addition, as DCGP Ltd is working in parallel with TII to deliver enabling works for the proposed new Metrolink, TII has also provided access to their Geotechnical information and reports.

Two Geotechnical Design Reports prepared by Jacobs Idom ML1-JAI-GEO-ROUT_XX-RP-Y-00003 | P03 2020/04/09 and ML1-JAI-GEO-ROUT_XX-RP-Y-00004 | P04 12/02/2021 have been provided by TII.

Information relating to the environmental ground conditions has been obtained from ground investigations (GI) carried out by O'Callaghan Moran & Associates (OCM) on behalf of T.J. O' Conner & Associates in August 2008. The GI comprised of 11No. shell and augur boreholes and 15No. rotary boreholes, soil analysis, and groundwater sampling.

Table 1 Summary of Ground Conditions

Stratum	Area covered	Estimated Thickness (m)	Typical Description
Superficial deposits			
Made Ground	Entire Site	2 – 5.2	Brown clayey with cinders and fragments of rubble and brick, increasing in thickness towards the eastern Site boundary.
Alluvium	Entire Site	5 – 20	Medium dense to dense sandy GRAVEL with occasional sand and silt layers. The gravel directly underlies the Made Ground and decreases in thickness towards the east/southeast Site corner
Till	Entire Site	5 – 10	Stiff to very stiff fine-grained CLAY with varying amounts of gravel, cobbles, and boulders.
Bedrock Deposit			
Lucan Formation	Entire Site	300 – 800	Dark grey to black, fine-grained, occasionally cherty, micritic Lucan Formation that weathers paler, usually to pale grey. There are rare dark coarser grained calcarenite limestone sometimes graded, and interbedded dark-grey calcar. The top of the Lucan Formation is encountered between 17mbgl and 27mbgl. A 1.0m thick weathered layer is present at the top of the deposit.

A section of the geology on-site as identified during previous ground investigations is included in Figure 39.

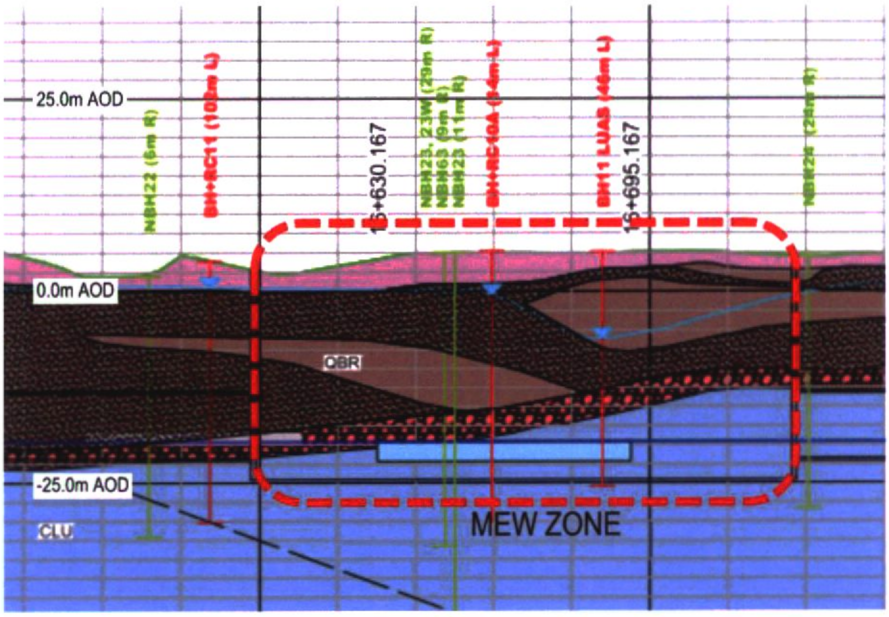

Figure 39 Ground Investigation Long Section - West to East Extracted from Jacobs/Idom DrawingML1-JAI-GEO-ROUT_XX-DR-Y-00021 P01.4 22/08/2019.

Contours of top of the weathered rock across the site, derived based on the available ground investigation information, are shown in Figure 40. Within Site 2 a significant variation in the level of the Limestone rock formation is observed across the site, from approximately -11m AOD towards the south of the site and becoming deeper in the north part of the site at approximately -19m AOD.

Figure 40. Top of Weathered Rock Across the Site (Isobars Indicating m AOD)

The geotechnical work provided by TII and by the previous developer were undertaken some time ago, a new SI has been commissioned by DCGP Ltd in late 2022/early 2023. The results of this are currently in the process of being interpreted but this has enabled the soil and rock properties and capacities to be reconfirmed. It has also provided more local data on the current ground water levels. A pumping test was also conducted to assess the permeability of the ground.

The interpretive report will be prepared in June 2023 based upon the latest Causeway test results.

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6. Hydrology

6.1 Short Term Dewatering

A groundwater seepage analysis based upon the new Causeway data obtained by a pumping test in February 2023 has been carried out using Plaxis 2d, to simulate the full-scale pumping test results. For the sake of simplicity, steady-state conditions have been simulated, considering a constant dewatering rate of 7.7m^3/h and a 20m groundwater drawdown at the well location.

The analysis assumes axisymmetric geometry and seepage mechanism. An indicative view of the Plaxis 2d model showing estimated groundwater head distribution is presented in Figure 41.

The key model variables are the rock hydraulic conductivity (permeability - k) and the horizontal distance of the model right boundary (where the groundwater head within the limestone rock is unaffected by the pumping) from the model axis. The two have been estimated trying to mimic the observed dewatering rate and a relatively nominal drawdown (less than 1m) at distances in the order of 40-50m from the well, as observed in a number of nearby monitoring boreholes during the test.

A model boundary 60m away from the well (model axis) has been adopted, in combination with a mass permeability of 3.8x10^{-6}m/s for the Limestone. In reality, the Limestone permeability is primarily driven by the rock fracturing pattern. However, for the sake of simplicity, the rock has been modelled as a homogeneous stratum, with an isotropic permeability.

The predicted groundwater drawdown profile in the upper part of the Limestone layer is presented in Figure 42. The findings of the pumping test back-analysis have been validated using closed form solutions for confined aquifers dewatering.

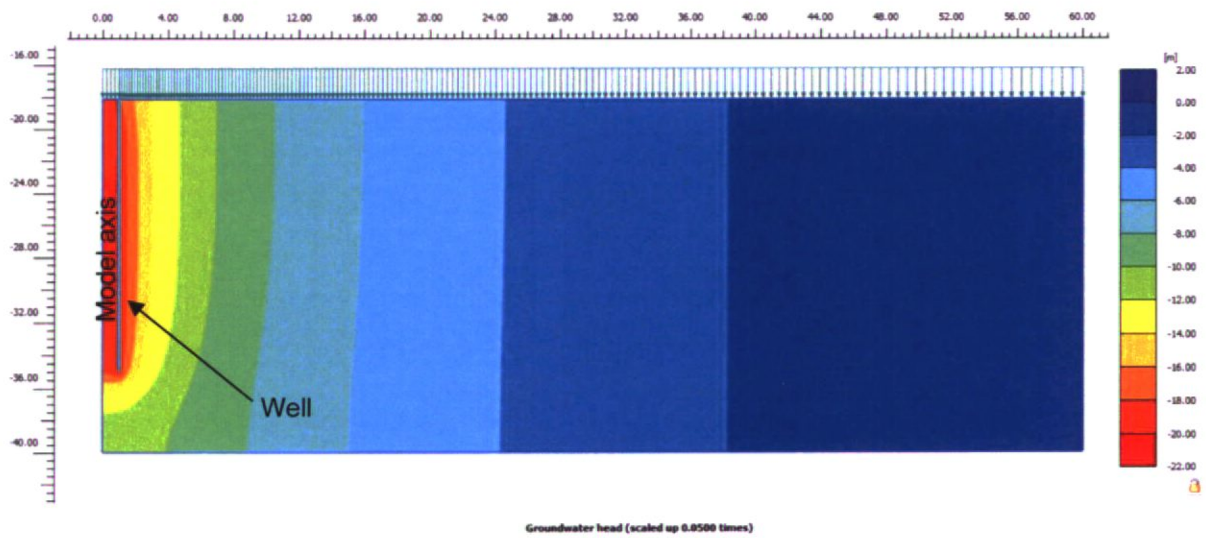

Figure 41 Pumping test back-analysis model – groundwater head (mOD) distribution (steady state pumping stage)

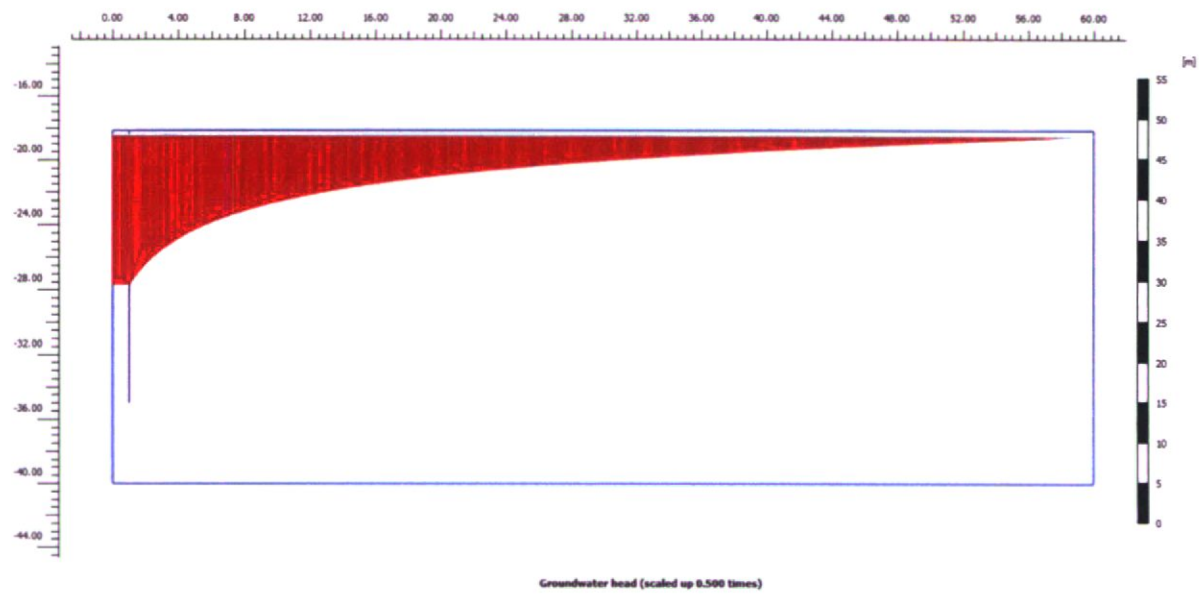

Figure 42 Predicted groundwater drawdown distribution within Limestone during pumping test.

6.2 Temporary dewatering assessment

An assessment of the likely dewatering rates during the proposed station box excavation has been carried out using Plaxis 2d. An indicative view of the model is presented in Figure 43 It is assumed that a number of wells will be installed along the box perimeter and will maintain a groundwater table to a level of 1-2m beneath the box formation level.

The assessment indicates that dewatering pumping rates in the order of $100m^3/h$ will be required for the entire box. It is anticipated that the groundwater extracted via the wells will be pumped back into the deep aquifer using additional recharge wells. Due to the relatively significant anticipated volumes of water, some form of grouting below the base of the excavation may be considered by the design and build contractor, in order to form a lower permeability "plug" and limit the dewatering volumes. It is worth considering that the grouted "plug" would have to extend to a sufficient depth, to prevent uplift stability mechanisms.

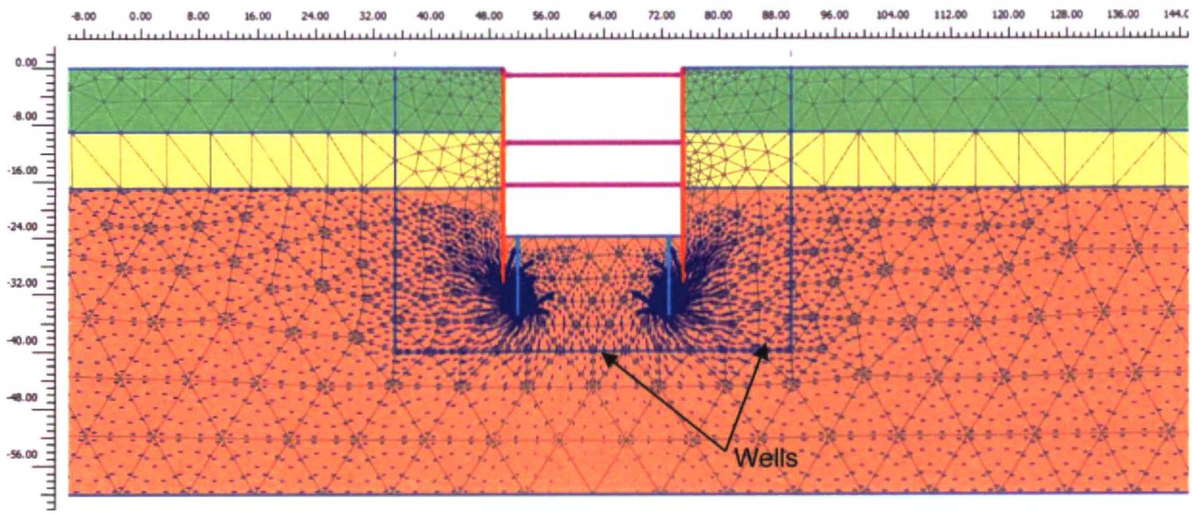

Figure 43 Groundwater flow vectors during dewatering

The main contractor will be required to manage the flow of water and will be required to submit details of the design of the dewatering proposals. This would also include the grout plug to reduce the volumes arising during the construction of the station box.

Buoyancy of the station box and the management of significant water pressure on the base slab will also need to be factored into the design.

6.3 Barrier Effect Assessment

The ground conditions at the site comprise superficial Made Ground, underlain by dense sands/gravels, followed by very stiff/hard clays and Limestone at depth. A groundwater aquifer is present in the superficial granular strata, with groundwater table at a level of approximately 0-1mOD. It is understood that a general groundwater seepage mechanism, with groundwater flow broadly in the north-west to south-east direction, is present.

As part of the proposed scheme development, the construction of an approximately 25m deep box, which will house the proposed O'Connell Street Station, is planned.

The deep box permanent structure will form a cut-off for the superficial groundwater flow and may induce groundwater head variations in the surrounding zone. A steady-state groundwater seepage simulation has been carried out, in order to estimate the potential "barrier effect" of the proposed box, and the associated changes in groundwater head distribution.

6.4 Ground Model and Groundwater

As DCGP Ltd and Transport and Infrastructure Ireland (TII) are both presenting information for DCGP Ltd planning application and TII railway order application, details of the ground water direction of flow has been shared across both project teams. In this way a co-ordinated and consistent baseline can be adopted for the purposes of the assessing the effect on the flow of ground water. A groundwater seepage mechanism is present within the superficial granular strata, in a general direction from north-west to south-east. This steady-state seepage mechanism, generally toward the River Liffey, has a groundwater head gradient of approximately 0.003. Figure 44 extracted from Jacobs IDOM report EGINF55-02/21 (rev 01) provides an indication of the current groundwater head distribution.

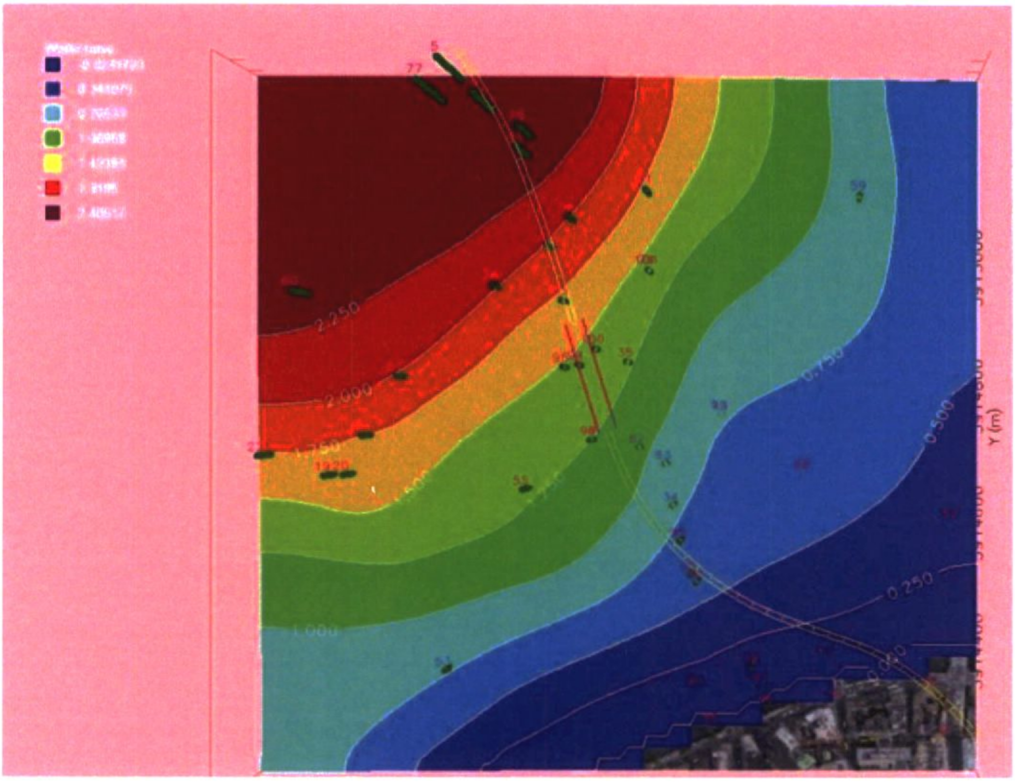

Figure 44 Groundwater head distribution in the O'Connell Street area (from Jacobs IDOM report EGINF55-02/21 – rev 01)

6.5 Groundwater Seepage Assessment

A groundwater seepage study has been carried out using the commercial software Plaxis 2d, simulating plane flow conditions across a horizontal cross-section, located within the superficial granular deposits. Two scenarios have been analysed, considering the current conditions and the presence of the proposed station box acting as a groundwater barrier. The aim of the analysis is to evaluate the magnitude of groundwater level increase on the "upstream" (north) side of the basement and the groundwater level reduction on the "downstream" (south) side, as a result of the groundwater damming effect.

A view of one of the models (with proposed station box) is shown in Figure 45. An indicative view of the groundwater seepage mechanism in proximity of the proposed box is shown in Figure 46.

Figure 47 shows contours of groundwater head in the zone surrounding the proposed development site. The groundwater boundary conditions adopted in the finite element analysis have been selected in order to broadly simulate a north-west to south-east groundwater flow pattern, as previously mentioned.

Figure 48 indicates the groundwater head distribution following the construction of the box.

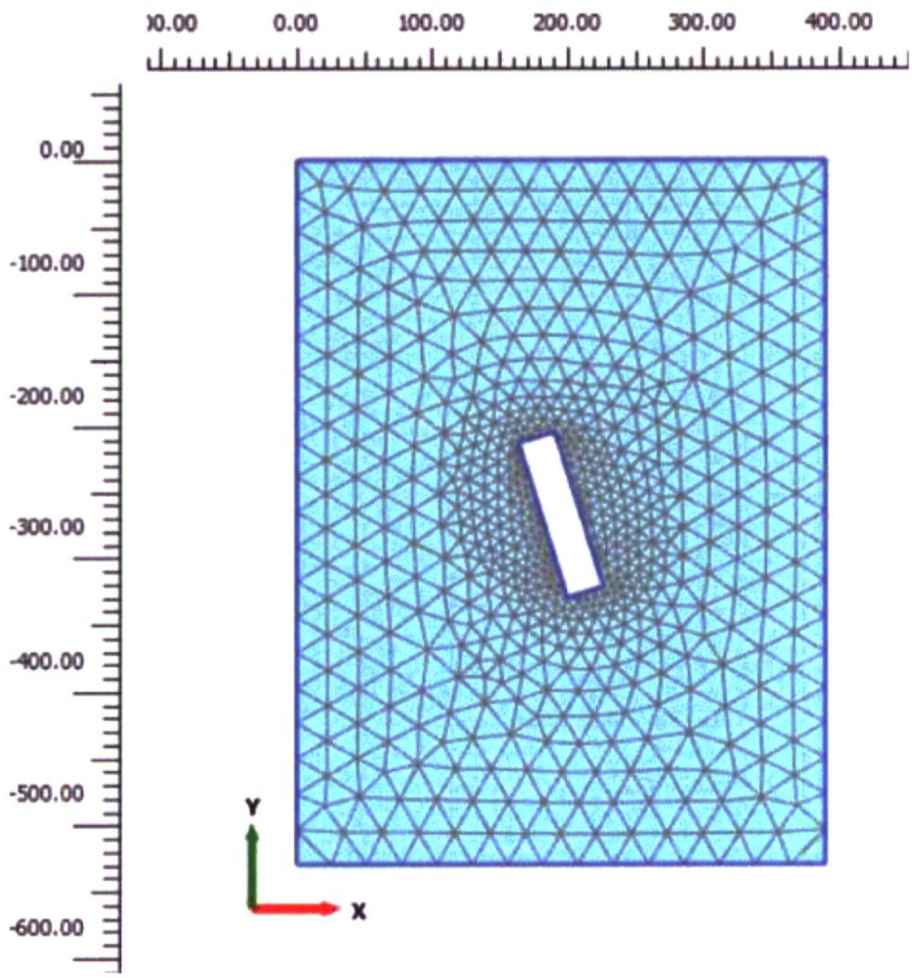

Figure 45 View of the Plaxis model

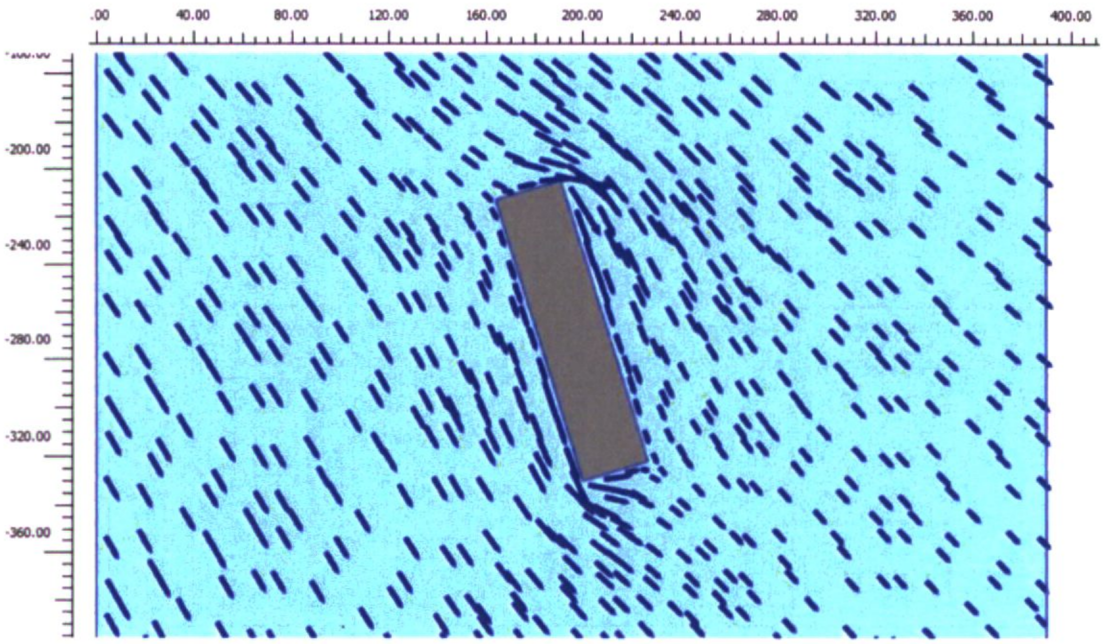

Figure 46 Indicative groundwater flow vectors in proximity of the proposed basement (vector size is proportional to groundwater seepage velocity)

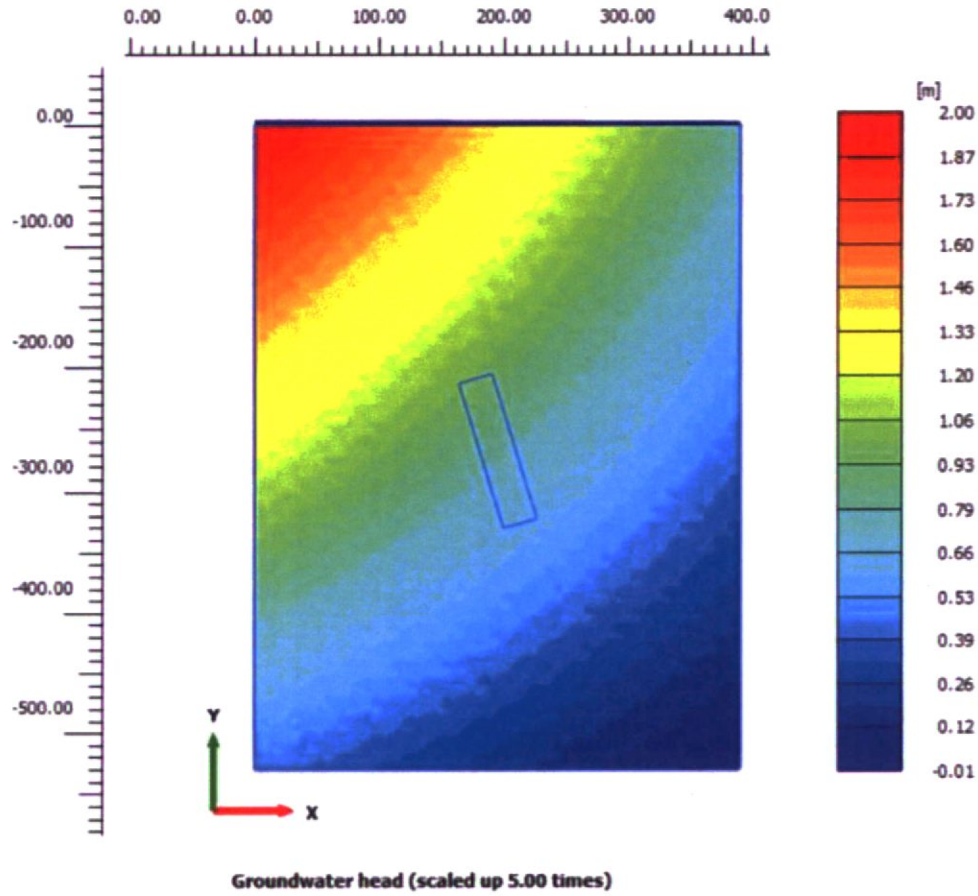

Figure 47 Groundwater head (mOD) distribution (current conditions)

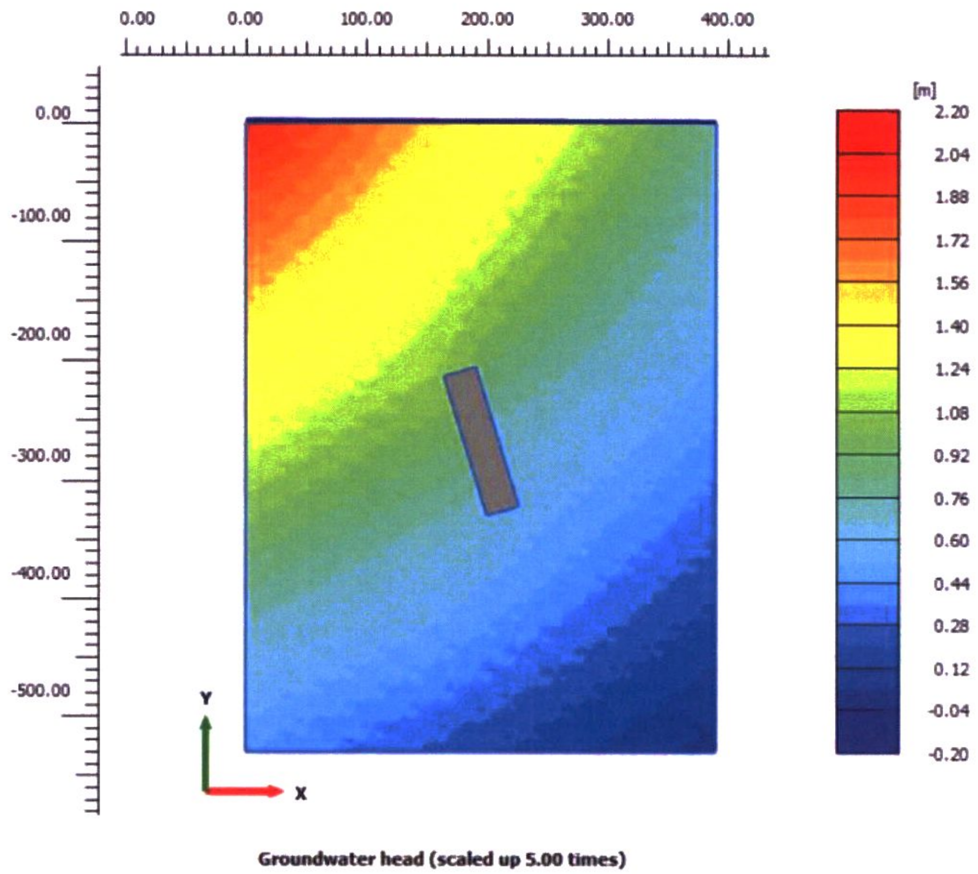

Figure 48 Groundwater head (mOD) distribution (after box construction)

Groundwater head variations (increase "upstream" and reduction "downstream") of up to 0.05m are predicted, which would indicate negligible impact of the proposed station box construction on the groundwater conditions in the area.

7. Construction Phase Building and Local Infrastructure Assessment

7.1 Study Aims and Objectives

A ground movement and impact assessment has been carried out in order to assess the resistance of the neighbouring buildings and infrastructure assets to ground movements caused during the excavation during the development works at Site 2 of Dublin Central redevelopment.

The scheme involves the following construction works:

- Demolition of the existing buildings present at the site.
- Installation of secant pile walls along the majority of the Site 2 perimeter and bearing piles across Site 2.
- Excavation of a single-storey basement across the entire Site 2 footprint.
- Installation of deep diaphragm walls along the perimeter of the proposed O'Connell Street Station box, part of the new proposed Dublin Metro.
- Excavation/construction of the approximately 25m deep box, which will house the new O'Connell Street Station.
- Construction of the proposed oversite development structures, which include a number of multi-storey buildings.

The GMA presented herein focuses on the temporary work construction stages, primarily comprising existing buildings demolition and basement/box excavation works.

The assessment encompasses properties located within the zone of influence of the proposed scheme. The GMA study is based on *greenfield* ground movements which are unlikely to be exceeded. The adopted methodology provides a robust and conservative assessment representative of current industry best practice, as detailed in Section 7.2.

The assessment carried out and described herein aims to:

- Assess the impact of ground movements induced by the proposed works on properties adjacent to the development under consideration.
- Inform liaison with neighbouring buildings owners.
- Provide performance criteria and inform aspects of substructure construction and design.

This section of the BIA provides a detailed description of the:

- Modelling parameters and input.
- Analyses and results.

7.2 Impact Assessment Methodology

7.2.1 Assessment Details

The assessment has been undertaken using proprietary spreadsheets and the commercially available software Oasys Pdisp and Xdisp, which consider the three-dimensional ground movement field induced by the proposed excavation works.

A series of three-dimensional models of the proposed scheme have been developed in Oasys Xdisp/Pdisp and combined by means of superposition, in order to enable ground movement assessments to be carried out representing the various construction stages. The following analysis was carried out:

Group A – Unloading ground movements (Pdisp)

- **Short Term Demolition** – proposed existing buildings demolition. A series of uniformly distributed loads has been modelled to simulate the removal of the existing dead loads at existing ground level (short-term conditions).

Group B – CIRIA-based ground movements (Xdisp)

- **Wall installation + Excavation** – secant piled walls/diaphragm walls and basement excavation.

The Group A assessments are based on *greenfield* ground movements evaluated from linear half-space (Pdisp) analyses and focus on vertical ground movements induced by the overburden removal unloading.

The Group B assessments adopt the normalised ground displacement curves reported in CIRIA C760. In addition to the effects arising from the basement excavation, the ground movement effects associated with the retaining systems installation have been considered. The following CIRIA C760 normalised ground movement curves were adopted to assess ground movements due to retention system installation and excavation works:

- *Secant piles walls installation*: 50% of installation of contiguous bored pile wall in stiff clay, based on guidance from technical paper published by Ball & Langdon (2014).
- *Diaphragm walls installation*: 50% of installation of planar diaphragm wall in stiff clay.
- *Station box excavation*: Excavation in front of a high stiffness wall in stiff clay (scaled in order to achieve a maximum horizontal movement of 20mm).

It is worth noting that ground movements induced by the excavation of the single storey basement for the oversite development have not been modelled, as survey information indicates the existing neighbouring buildings are founded at a similar level to the proposed single storey basement.

In order to estimate the ground movements induced by the proposed O'Connell Street Station box excavation, a number of retaining wall analyses have been carried out using the commercial software Plaxis 2d. Adopting a bottom up construction sequence, with three levels of relatively stiff temporary props, maximum wall deflections in the order of 20mm have been estimated. Therefore the CIRIA C760 ground movement curves adopted for the box excavation have been suitably scaled, in order to mimic a maximum horizontal movement due to box excavation equal to 20mm.

For the installation of secant piles and diaphragm walls, only ground movements due to installation above the limestone layer have been analysed. The depth of the limestone layer varies across the site: in the analyses, it is assumed a top of limestone layer at -12mOD in the southern portion of the site and -19mOD in the northern portion of the site.

An indicative view of the Xdisp models, including the excavation/retaining system installation areas and the existing buildings assessed in the analysis, is presented in Figure 49.

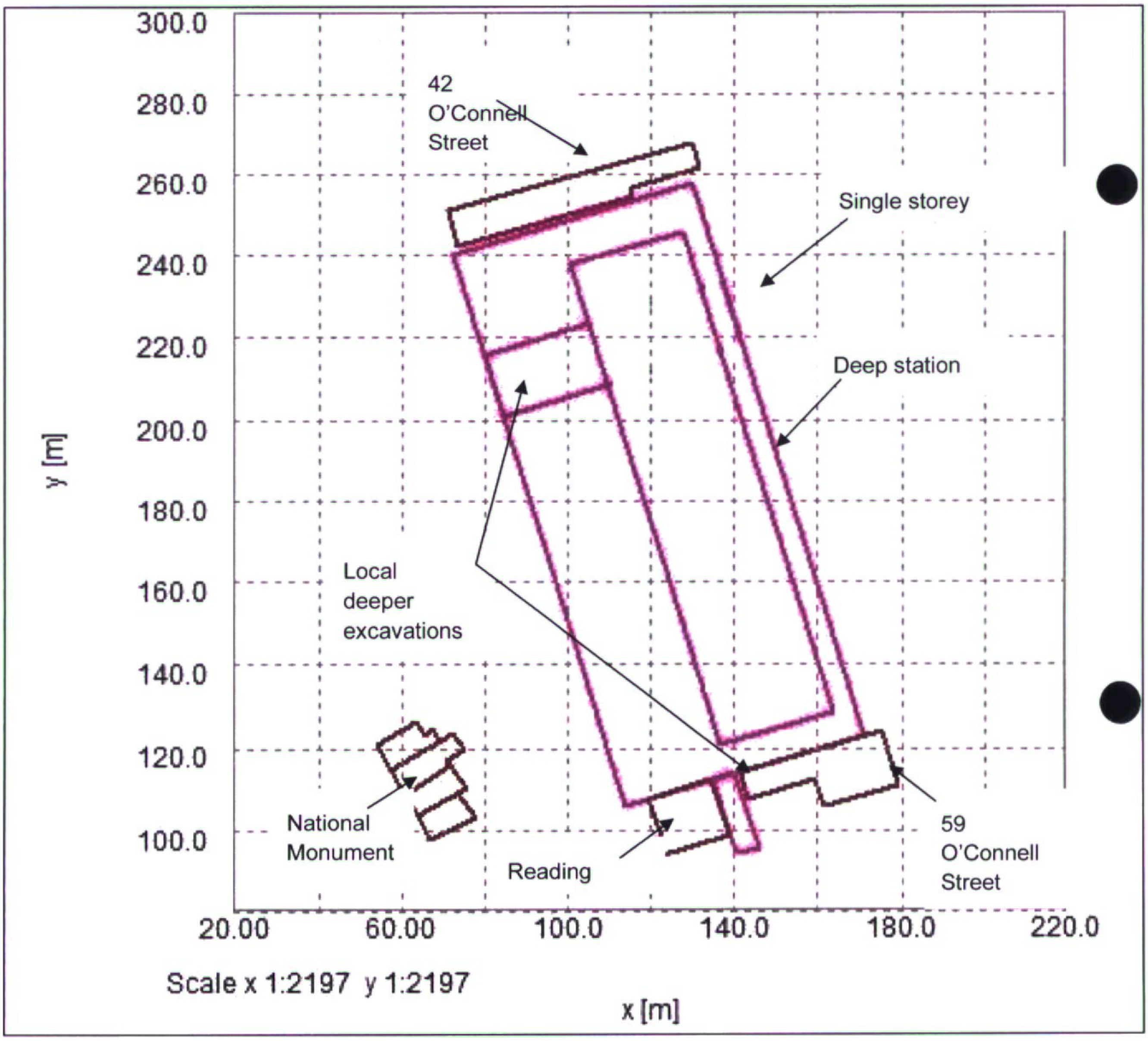

Figure 49 Indicative view of the Xdisp model (plan view)

7.3 Impact Assessment

7.3.1 General

The potential impact/damage induced on primary façade/wall elements of the buildings surrounding the proposed scheme has been evaluated on the basis of the calculated ground movement fields.

The masonry walls being assessed are shown in Figure 50 and Figure 51, including the wall nomenclature/reference system adopted. The arrangement is based on the currently available survey information and presents an array of masonry façades running both perpendicular and parallel to the proposed development site perimeter (covering the key deformation mechanisms). In total, 35no. façades of the neighbouring buildings were considered for the current study and these are grouped in the following manner:

- 42 OCS 1-6: 42 O'Connell Street.
- 59 OCS 1-6: 59 O'Connell Street.
- NM 1-17: National Monument.
- RR 1-6: Reading Room.

Figure 50 Nomenclature for each building façade/masonry wall element (northern portion of the site)

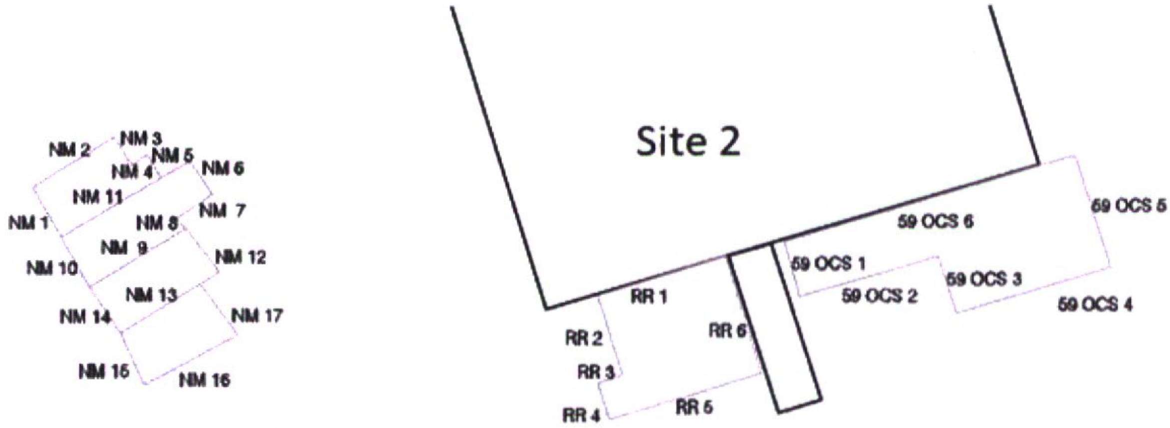

Figure 51 Nomenclature for each building façade/masonry wall element (southern portion of the site)

Each wall has been assumed to behave as an equivalent beam subject to a bending and extension/compression deformation mechanism, based on the evaluated greenfield ground movement, as outlined previously.

Tensile strains induced within the building masonry walls have been evaluated based on the deflection ratios Δ/L and horizontal extension mechanisms estimated from the analyses. The assessment considers the well-established Burland (1997) damage classification method, as presented and summarised in Figure 52 and Figure 53. This method involves a relatively simple but robust means of assessment, which is widely adopted and is considered to comprise an industry standard/best practice basis for impact assessments of this typology.

Potential damage categories are directly related to the tensile strains induced by the proposed construction stages, arising from a combination of direct tension and bending induced tension mechanisms. The evaluated damage categories correspond to an unlikely to be exceeded scenario (on the basis of the data sets adopted and greenfield assumptions).

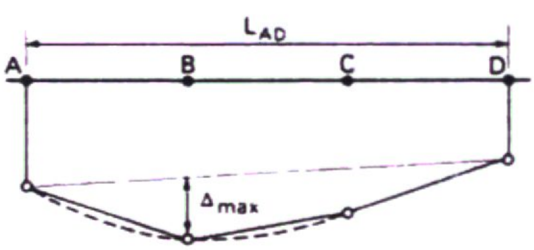

Figure 52 Definition of relative deflection Δ and deflection ratio Δ/L

Category of damage	Description of typical damage (ease of repair is underlined)	Approximate crack width (mm)	Limiting tensile strain ε_{lim} (per cent)
0 Negligible	Hairline cracks of less than about 0.1 mm are classed as negligible.	< 0.1	0.0–0.05
1 Very slight	Fine cracks that can easily be treated during normal decoration. Perhaps isolated slight fracture in building. Cracks in external brickwork visible on inspection.	< 1	0.05–0.075
2 Slight	Cracks easily filled. Redecoration probably required. Several slight fractures showing inside of building. Cracks are visible externally and some repointing may be required externally to ensure weathertightness. Doors and windows may stick slightly.	< 5	0.075–0.15
3 Moderate	The cracks require some opening up and can be patched by a mason. Recurrent cracks can be masked by suitable linings. Repointing of external brickwork and possibly a small amount of brickwork to be replaced. Doors and windows sticking. Service pipes may fracture. Weathertightness often impaired.	5–15 or a number of cracks > 3	0.15–0.3
4 Severe	Extensive repair work involving breaking-out and replacing sections of walls, especially over doors and windows. Windows and frames distorted, floor sloping noticeably. Walls leaning or bulging noticeably, some loss of bearing in beams. Service pipes disrupted.	15–25 but also depends on number of cracks	> 0.3
5 Very severe	This requires a major repair involving partial or complete rebuilding. Beams lose bearings, walls lean badly and require shoring. Windows broken with distortion. Danger of instability.	usually > 25 but depends on number of cracks.	

After Burland et al. 1977, Boscardin and Cording 1989, and Burland 2001.

Figure 53 Building damage classification – relationship between category of damage and limiting strain ε_{lim}

7.3.2 Results

The results of the assessment are presented in Table 2. The results presented in this table represent the worst-case output arising from all analysis runs, and only present values for a Damage Category greater than *Category 0 - Negligible.*

Ground movement contour plots are shown below.

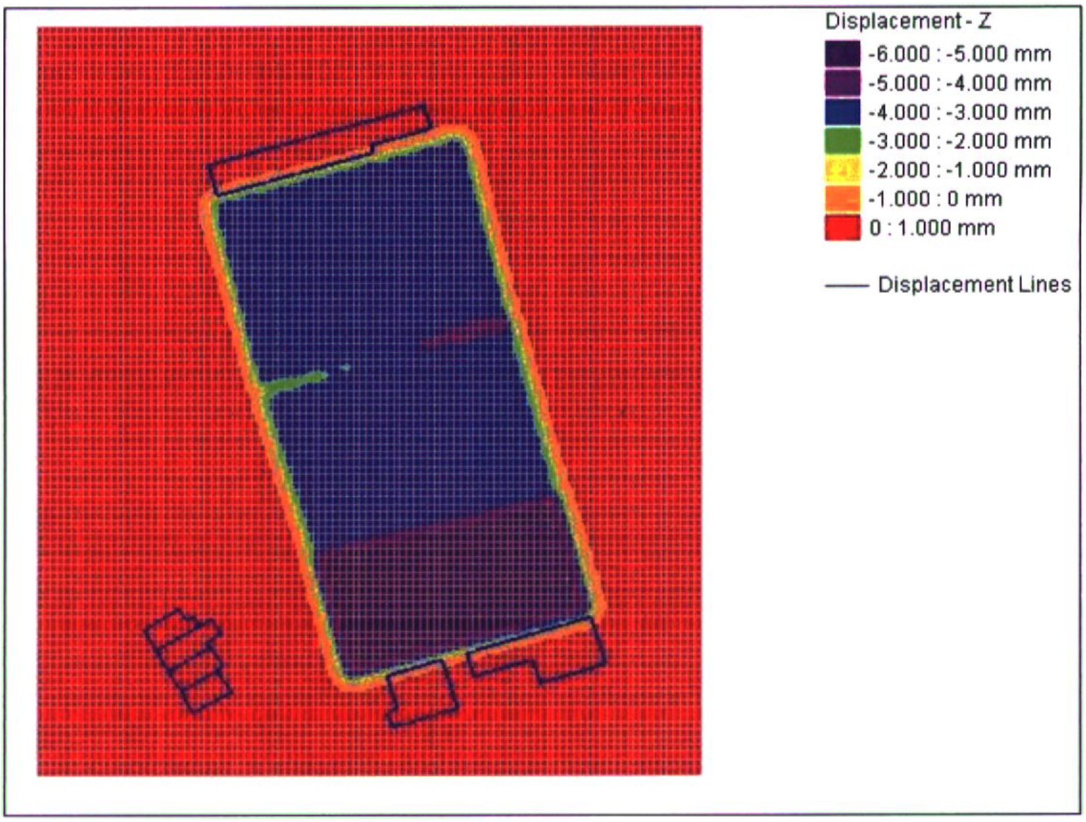

Figure 54 Short Term – Demolition.

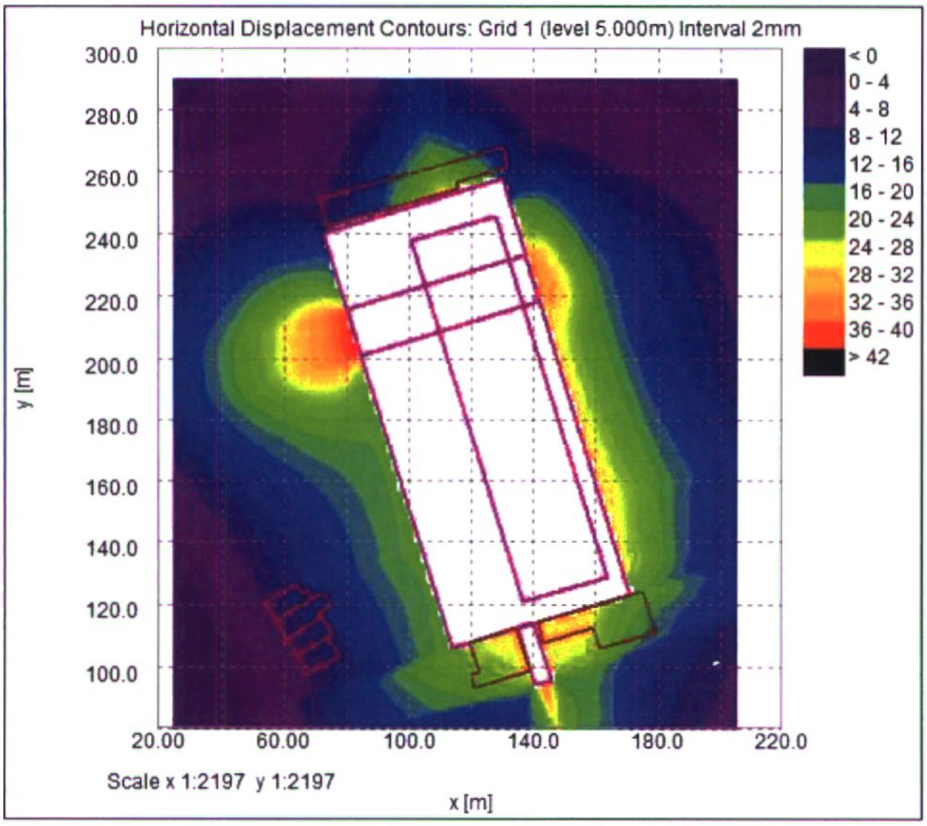

Figure 55 Horizontal Displacement – Wall Installation and excavation.

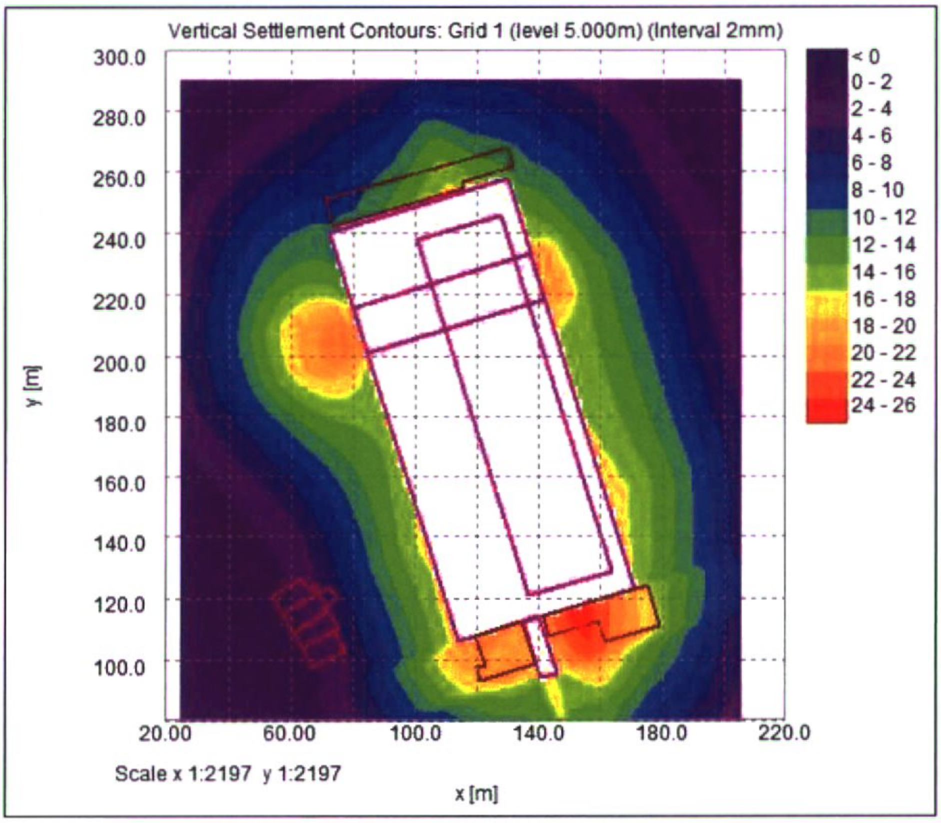

Figure 56 Vertical Settlement – Wall Installation and Excavation.

Table 2 Evaluated damage categories extracted from Xdisp

Façade Reference	Stage	
	Demolition	Excavation
42 OCS 2	Category 0 – Negligible	Category 1 – Very Slight
59 OCS 1	Category 0 – Negligible	Category 1 – Very Slight
59 OCS 2	Category 0 – Negligible	Category 1 – Very Slight

Note: This table excludes the façades that have a Damage Category 0 for all stages.

7.4 Assessment of the LUAS

The Luas light railway line is located in the central reservation area of O'Connell Street Upper.

An indicative view of the Xdisp models, including the excavation/retaining system installation areas and the existing buildings assessed in the analysis, is presented in Figure 57.

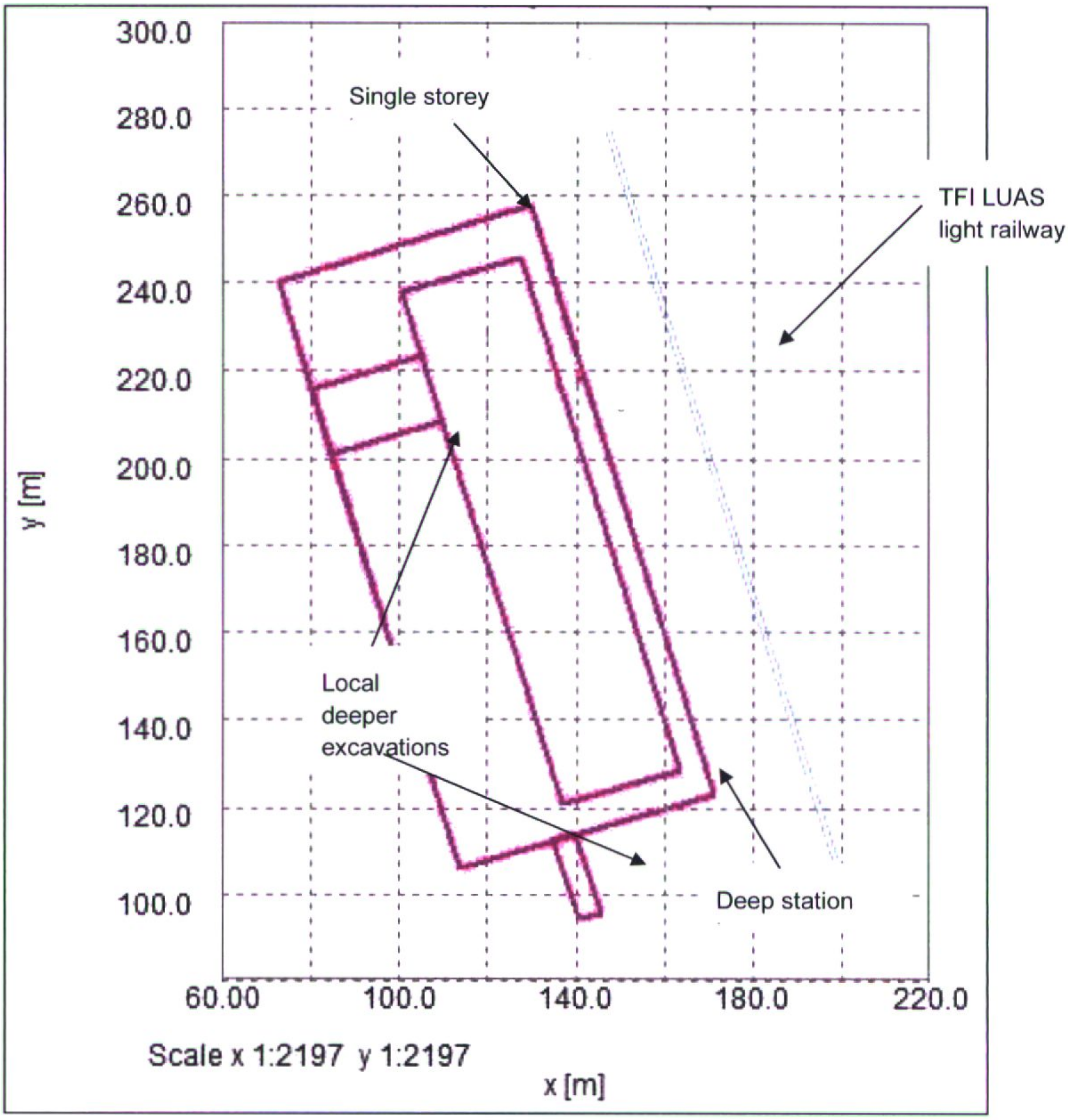

Figure 57 Indicative view of the Xdisp model (plan view)

7.5 Ground Movement Assessment Criteria

The potential impact induced on the existing LUAS light railway has been evaluated on the basis of the calculated ground movement fields. The differential settlement between the two parallel rails (cant) and the change in cant along the line of the track (twist) are derived from the vertical displacements calculated from the aforementioned analyses.

The rail tracks are assessed by calculations of twist and cant based on equations presented in Figure 110

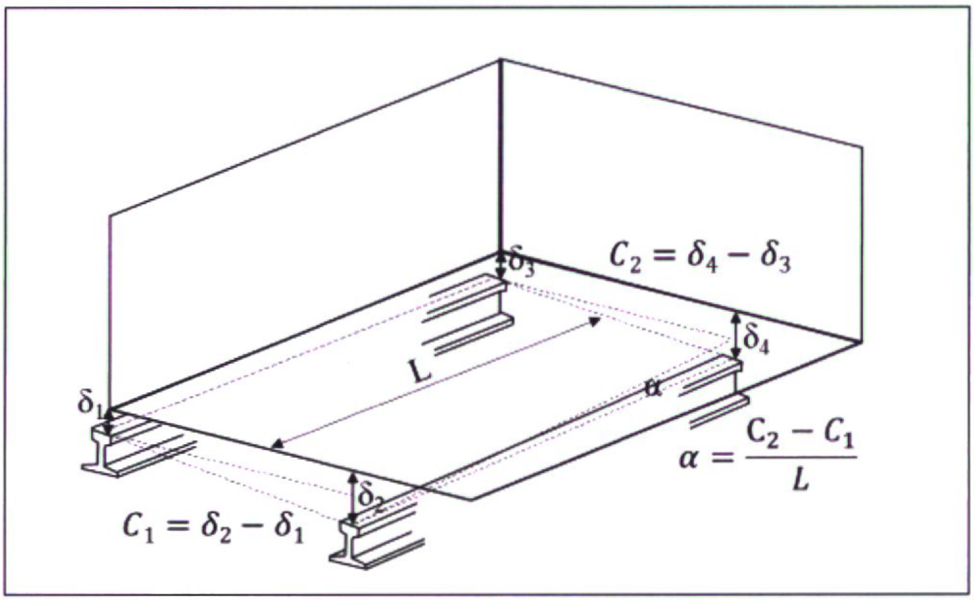

Figure 58 Cant and Twist Assessment

Where:

L = span (base) for twist calculations.

δ = vertical lining movement at bottom of the lining (left and right).

C = Cant.

α = twist (the change in the cant over the base distance, reported in units of displacement)

The Luas assessment criteria for light rail tracks are presented in Table 3. All information presented is based on the Code of engineering practice for works on, near, or adjacent the Luas light rail system (2016).

Table 3: Luas light rail system settlement trigger levels

Trigger Level	Settlement per 20m	Measures
AMBER	4.0	Maintain Luas operations with reduced speed
RED	6.0	Halt operations until corrective measures in place

7.6 Assessment Results

The potential impact induced on the existing LUAS light railway has been evaluated on the basis of the calculated ground movement fields. The vertical displacement and cant results for the track are provided in Table 4 and Table 5.

Figures 56 and 57 show the vertical movements obtained in the analysis at demolition and end of excavation stages, respectively.

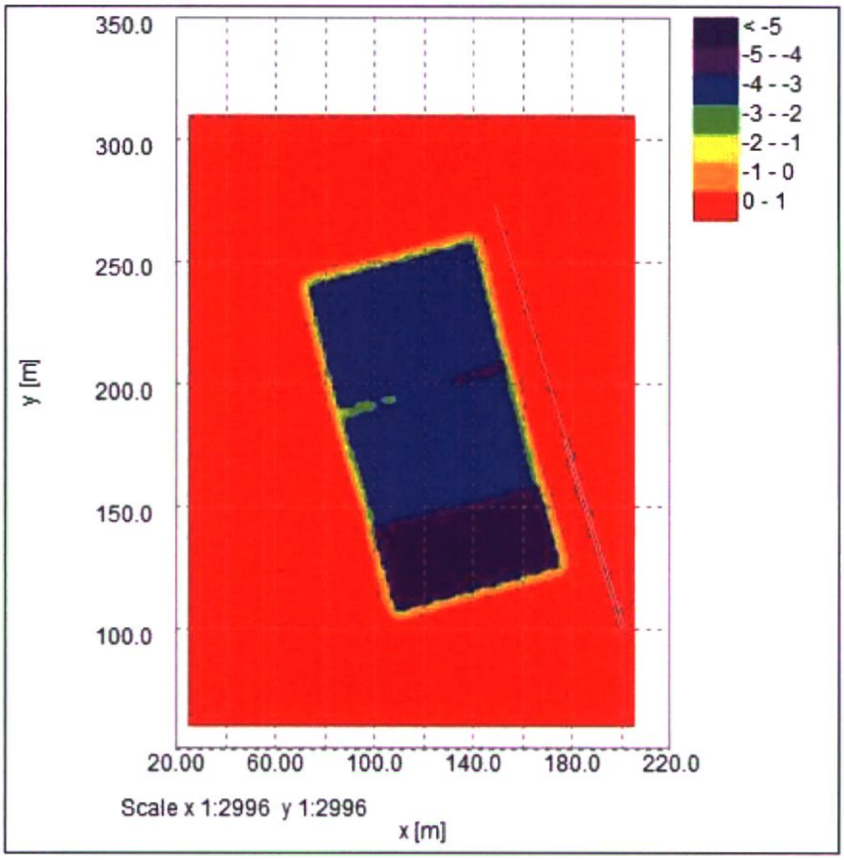

Figure 59 Vertical displacement contours at ground level (demolition)

Waterman

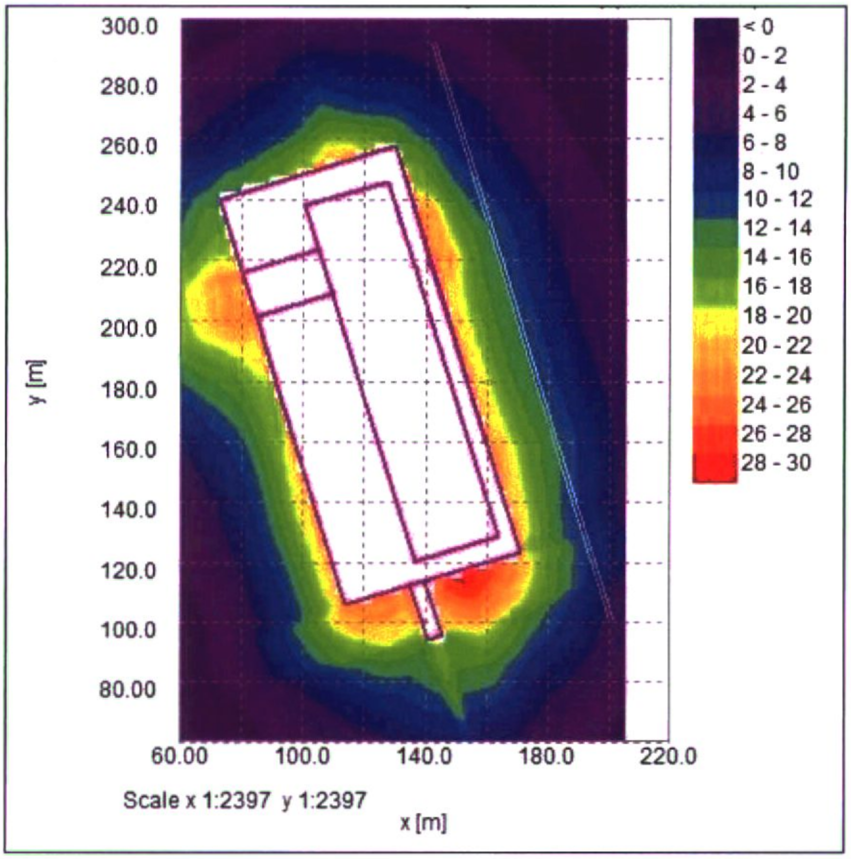

Figure 60 Vertical displacement contours at ground level (wall installation and excavation)

Table 4 Maximum vertical track settlements

Maximum Track Vertical Settlement (mm)	
Demolition	Excavation
0.15	12.54

Table 5 Maximum track cant and twist

Demolition		Excavation	
Cant (mm)	Twist at 3m intervals (mm)	Cant (mm)	Twist at 3m intervals (mm)
0.0	0.0	0.5	0.1

The predicted cant, twist (at 3m intervals) and vertical settlement profiles of the rail track following wall installation and excavation are presented in Figure 58 to Figure 60.